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MEDICAL DEPARTMENT, UNITED STATES ARMY

SURGERY IN WORLD WAR II

Volume II

GENERAL SURGERY

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SURGERY IN WORLD WAR II

Prepared under the direction of

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Historical Unit, Army Medical Service

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GENERAL SURGERY

Volume II

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Foreword

This volume on general surgery is set apart from other volumes of the history of the Medical Department of the United States Army in World War II by a number of special considerations.

This is a story not only of surgery performed in forward Army medical units, but of extremely urgent surgery; all abdominal injuries constituted emergencies, and all casualties with abdominal injuries were nontransportable. This volume is also the record of the performance of an auxiliary surgical group, and as such is typical of the outstanding work done in all theaters of operations by the medical officers assigned to similar units, as well as by medical officers organically assigned to frontline hospitals in which surgical teams from auxiliary surgical groups were employed.

The 3,154 abdominal injuries upon which this story is chiefly based were all the result of the violence of war, and all but about a hundred were combat incurred. This is perhaps not the largest series of combat injuries of the abdomen ever to be recorded, but it is undoubtedly the largest series to be analyzed in such detail. This series, furthermore, has the great advantage, which most recorded series do not possess, that the analysis of cases was planned in advance. There are some statistical inadequacies, it is true. They were inevitable in the circumstances in which the data were collected. These inadequacies, however, in no way alter the clinical conclusions which were arrived at by the experienced surgeons who made the analysis and which, incidentally, were merely the confirmation of the clinical impressions which had already become evident. The data were analyzed overseas, immediately after they were collected. They were reanalyzed later, in the more normal environment of the United States, when more sober second thoughts were possible. The analysis is entirely objective. Errors of technique and mistakes of judgment are related as frankly as are surgical triumphs.

At the beginning of World War I, the policy of management of combat-incurred abdominal injuries was one of so-called surgical abstention. As the war progressed, the undesirability of such a policy became more and more evident, and surgical intervention began to be practiced, but for a variety of reasons, including lack of organization, operation was still not the general rule when the war ended. In World War II, as the result of both the previous military experience and the intervening civilian experience, the official policy was to operate, as promptly as possible, on all casualties with abdominal injuries in whom the mere act of operation would not be fatal. Only a small number of patients (considerably less than 1 percent) fell into this category.

The policy of prompt surgical intervention in abdominal injuries was made practical and possible because of another concept that was new in World War II, the practice of preoperative resuscitation, which is also described in this volume. Many of the fatalities in World War I occurred because the patients

were never in condition to be operated on. In World War II, a small number died while resuscitation was being attempted, but at least the attempt had been made to bring them to a status in which surgery could be tolerated. The liberal use of whole blood was the central feature of resuscitation, but, as Doctor Beecher points out in his account of the program, every detail was important, from the placing of blankets underneath the patient, as well as over him, to the deliberate care with which his position was changed on the operating table. The program of resuscitation, combined with competent anesthesia, permitted surgery of great magnitude on patients whose initial condition was such that in an earlier day they could only have been left to die.

Three extremely important departures from previous medicomilitary practices require specific mention. The first is the management of wounds of the rectum and large bowel by colostomy, with or without exteriorization of the damaged segment. Although colostomy had been an established procedure in civilian surgical practice before World War I, it was used only in desperate cases in that war and was never routine, even when surgical intervention in abdominal injuries had become fairly general. United States Army medical officers used colostomy in the fighting in North Africa in 1942 and 1943 without knowledge of the previous British experience with it. The results were so good that its use became official Medical Department policy in October 1943. The performance of colostomy saved thousands of lives immediately after wounding, and the excellence of the final results is described in the last chapter of this volume, which deals with the repair of colostomy in Zone of Interior hospitals.

Wounds of the liver were never treated surgically in World War I, even after the policy of surgical intervention for abdominal injuries had been introduced. Their management in World War II represents a process of evolution, since the military surgeons who encountered them had no decisive principles to guide them other than the general policy that surgical intervention in abdominal injuries is in the best interests of all patients who survive to reach forward hospitals. Drainage of Morison's pouch, which eventually became established practice, resulted in a considerable salvage of life, as well as in a considerable reduction in both primary and postoperative complications in injuries of the liver.

The transdiaphragmatic approach to thoracoabdominal wounds, of which there were 839 in this series, represents a new practice in military surgery. The cardiorespiratory risks associated with this technique were reduced to a minimum by the ready availability of competent anesthetists and suitable anesthetic equipment. The ease of intimate surgical exploration of the left upper quadrant, in properly selected cases, by way of this incision is evident in the good results achieved in injuries of the spleen, in which, in contrast to World War I practice, splenectomy was the accepted method of management in World War II.

The 333 negative explorations in this series are, in some respects, the most important group of all. One of the outstanding observations in this analysis

was that in not a single instance did a missile pass harmlessly across the general peritoneal cavity in a major diameter. The prompt exploration of every case in which there was any suspicion of penetration of the peritoneal cavity was therefore standard practice and was entirely justified, in view of the minimal mortality associated with exploration and the risks involved in nonsurgical management of penetrating abdominal wounds. These 333 negative explorations may, in a sense, be described as unnecessary emergencies, but they well illustrate the surgical philosophy which directed the management of abdominal injuries in World War II.

I should be derelict if I brought this foreword to a close without specific recognition of the technical competence, sound professional judgment, and surgical courage of the members of the 2d Auxiliary Surgical Group who handled these cases, and without paying tribute also to the indispensable assistance they, like all other military surgeons, received from the anesthetists and the resuscitation teams whose part in the management of abdominal injuries is described in this volume.

S. B. HAYS,
Major General,
The Surgeon General.

Preface

Prevailing United States Army doctrines in 1942 held that a combat force could best be supported by activating methods and procedures generally known at the outbreak of war. Exception was made for new developments which were expected to emerge from an intense scientific effort in this country, specifically that fostered by the Office of Scientific Research and Development, with the advice of the National Research Council. Otherwise, combat in the field was pictured as calling for the replacement of personnel and supplies and a reasonable modicum of skill in the adaptation of standardized procedures to specialized situations as they were encountered. It was not generally understood that experience in the field could point the way toward immediate and radical changes of methods and equipment and that quick footwork in making these changes spelled survival. To be sound, changes of this type required as much factual evidence as could be assembled.

As a consequence, no provision was made for the collection and analysis of surgical evidence so that corrective measures might be devised by those on the spot when confronted with unexpected happenings. The idea of sending out skilled observers to identify new problems and solve them then and there was not entertained. In fact, such an idea smacked of the academic and was dismissed by the stern reminder that medicine was on the march to help fight a war—not to indulge in research.

Interestingly enough, it was the combat components that pointed the way by the utilization of the services of experts to observe and report on the performance of machines of war. Many were the “bugs” that remained in new tanks, planes, and missiles, and these defects were constantly being ironed out. Precise and scientific measurement of novel developments by the enemy required alert and expert intelligence. One recalls the encounter with magnetic mines that threatened shipping in the North Atlantic. Combat commanders and their conventional military staffs cannot be expected to solve such problems unaided and, in fact, may not even be able to define them in terms that can lead to a solution elsewhere. The same may be said of a wound surgeon confronted by a case of anuria in a forward hospital.

Beginning in the North African campaign and continuing through Sicily, Italy, and southern France, the surgeons of the theater were hard pressed by the need for surgical evidence to guide their daily work. Some of the first compilations of the records of patients who had disappeared into the evacuation stream were made as followup studies by members of the 2d Auxiliary Surgical Group. This was partly because the surgical teams had periods of inactivity that could be devoted to such pursuits and partly because of the wise insistence

of their commanding officer, Col. James H. Forsee, MC, on maintaining duplicated and full clinical records. It could have been so easy to let down standards and be too busy to keep records adequate for analysis.

The theater from which the greater part of this volume has originated was also fortunate in the assignment of affiliated hospital units from leading teaching hospitals with chiefs of surgery who insisted on the maintenance of high standards. A professor of surgery from Oslo, after 3 weeks in the forward area of the Fifth United States Army in Italy, said: "You are holding to the standards of university clinic surgery under fire and in tents with mud floors."

Finally, the small group of peripatetic officers who were identified as consultants were not deployed with the mission of commissars or gauleiters. They were searching for surgical evidence by direct observation and discussion. The achievement of a consultant was aptly described by Sir Patrick Berkeley Moynihan, following World War I:

"I have gathered a posie of other men's flowers and nothing but the thread that binds them is mine own."

Of course, the Mediterranean Theater of Operations provided a favorable environment for such undertakings. It was an experimental laboratory not only for surgery but also for medicine as a whole; for ordnance; for equipment; and, as many are reluctant to recall, even for rations. It was vital that wound surgery be carried on within a framework of inquiry, for this theater was the proving ground for the greater task that was to come.

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Acknowledgments

Without the contribution of the authors of this book, made with no material reward and at the sacrifice of time and expenditure of energy which professional men can ill afford, there would not have been this history of surgery in World War II, and the many valuable lessons learned in the surgical care of battle casualties would not have been recorded.

The counsel and assistance of the Advisory Editorial Board in many matters is equally and gratefully recognized. Members of this board, individually and collectively, have given generously of their knowledge and experience in a consultative and advisory capacity.

Much credit is due Miss Elizabeth M. McFetridge, associate editor, for her skill and untiring labor in consolidating, organizing, rewriting, and perfecting the manuscripts for this book.

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All illustrations were prepared for publication by Mr. R. Pierce Thompson, under the direction of Mr. Herman Van Cott, chief, Medical Illustration Service, Armed Forces Institute of Pathology.

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Part I

RESUSCITATION, CONTROL OF
PAIN, AND ANESTHESIA

CHAPTER I

Resuscitation of Men Severely Wounded in Battle

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THE EVOLUTION OF METHODS OF RESUSCITATION IN THE MEDITERRANEAN THEATER

The fighting in the Mediterranean (North African) Theater of Operations in World War II began in November 1942 and ended early in May 1945. As a whole, the campaigns carried out during this time were among the longest fighting conducted by any American army since the Civil War. From the medical standpoint, and entirely aside from any military considerations, the duration of combat provided the inestimable advantage of time for the evolution of sound medical practices, for the correction of errors, and for the development of expeditious medicomilitary methods.

The two case histories which follow illustrate excellently how, over this period, earlier, erroneous concepts of therapy gave way to advanced, sounder concepts:

Case 1.—On 21 March 1943, during the fighting in Tunisia, an infantryman sustained a compound fracture of the left humerus and a laceration of the left side of the chest from a shell fragment. He was tagged at a regimental aid station at 1100 hours. First aid consisted of the intramuscular injection of 30 mg. (gr. $\frac{3}{4}$) of morphine and the application of sulfanilamide-powdered dressings and a Thomas arm splint. At the division clearing station, the man was given 1 cc. of tetanus toxoid and 500 cc. (2 units) of blood plasma. His general condition was not described on the medical tag.

During the afternoon of the same day, the patient was evacuated to a field-type hospital. At 1715 hours, his blood pressure was recorded as 110/70 and his pulse rate as 120. Examination revealed absent breath sounds and hyperresonance on the left side of the chest, with abdominal rigidity and tenderness. At 1745 hours, he was given a second transfusion of 500 cc. (2 units) of blood plasma. Roentgenologic examination of the left arm revealed a fracture of the lower third of the humerus, with lateral bowing. Fluoroscopic examination of the chest and upper abdomen showed increased density in the left hemithorax; the mediastinum was pushed over to the right, apparently by fluid. A large foreign body was observed in the region of the stomach. As there was no evidence of sucking in the chest wound, it was closed by suture. The diagnosis at this time was a combined thoracoabdominal wound, with rupture of a viscus and probable hemorrhage.

The blood pressure at the time the fluoroscopic examination was conducted was satisfactory, and the pulse was of fair quality. Immediate operation was therefore undertaken, after a transfusion of 500 cc. of whole blood. As soon as the abdomen was opened, through a long left rectus incision, there was a gush of blood and air. Respiratory difficulty was apparent immediately. The patient's condition improved after a 4-cm. laceration of the

*Except as otherwise noted, part I is based upon the personal experience of the author as consultant in resuscitation and anesthesia, North African-Mediterranean Theater of Operations, and upon reports submitted to him.

dome of the abdomen had been closed. A 10-cm. laceration of the stomach, near the greater curvature, was also closed. It had been caused by a shell fragment 1 by 1 by 3 cm. The only other intraperitoneal injury was a small laceration of the spleen, which was not bleeding. The incision in the abdominal wall was closed after 12 gm. of sulfanilamide powder had been dusted into the peritoneal cavity.

Shortly after the operation had been concluded, sucking became apparent in the chest wound at the site of entrance of the missile, where simple suture closure had been done. Closed drainage was established at once, and the wound was packed tightly with vaseline gauze. The patient became deeply cyanotic, in spite of these measures, and died 21 March at 2315 hours, a little over 12 hours after injury.

Case 2.—On 21 April 1945, during the fighting in the Po Valley, a 26-year-old infantryman received compound fractures of the left femur and both ankles, a penetrating wound of the chest with hemothorax, and multiple lacerations of the legs and face from shell fragments. In the collecting station, to which he was brought at 1315 hours, 15 minutes after injury, he was given 15 mg. (gr. $\frac{1}{4}$) of morphine and 1,500 cc. (6 units) of blood plasma. Dressings were applied to his various wounds, and his legs were supported by splints. He was then evacuated to a clearing station, where he was given another 250 cc. (1 unit) of blood plasma and 20,000 units of penicillin intramuscularly. Because of his exceptionally poor appearance, he was also given a transfusion of 1,000 cc. of whole blood, which was obtained from the adjacent field hospital. His blood pressure was then 90/60.

When the patient was received in the field hospital at 2100 hours, his blood pressure was not measurable. His face was pale, but the skin was warm. The extremities were cool, and the veins were collapsed. He was classified as in severe shock. Laboratory studies showed the hemoglobin to be 9.8 gm. percent; the hematocrit 29; and the blood volume 5,010 cc., or 19 percent below his normal calculated blood volume. When the values were corrected for fluids which had been administered, it was found that, since wounding, he had lost 76 percent of his normal blood volume and 55 percent of his normal hemoglobin.

In the 4 hours which followed his admission to the field hospital, the patient was given 500 cc. (2 units) of plasma, 2,000 cc. of whole blood, and 25,000 units of penicillin intramuscularly. At the end of this period, his blood pressure had risen from 0 to 110/65, and his pulse was 138 and of good volume.

Operation was performed at 0330 hours 22 April, 14½ hours after wounding, under endotracheal nitrous oxide-ether anesthesia. It lasted 2½ hours. It consisted of a guillotine amputation of the lower third of the left leg, together with debridement of the wounds of the extremity and chest wall. Twenty-five thousand units of penicillin were placed in the right pleural cavity, after 1,000 cc. of blood had been aspirated from it. Nasal oxygen was instituted as soon as the operation was ended. Blood was also used liberally in the postoperative period.

The patient made a rapid, uncomplicated recovery.

Comment.—The first of these patients, who was clearly desperately wounded, was resuscitated by 4 units of plasma and 500 cc. of whole blood. Although the blood pressure was finally recorded as normal, the pulse, which continued rapid and of only fair quality, provided evidence that resuscitation had been inadequate. It was not possible to determine from the record the gravity of the pneumothorax that seems to have caused this man's death, or to determine whether a bilateral pneumothorax was overlooked, but the failure to tolerate accidents during and soon after operation was entirely characteristic of the seriously wounded, bled-out casualty who, in the first months of fighting in the North African theater, was resuscitated by plasma but did not receive adequate blood replacement.

The second patient, who was also desperately wounded, was resuscitated by

2,250 cc. of blood plasma (9 units) and 3,000 cc. of whole blood. In addition, blood was used liberally during the postoperative period to overcome acute anemia and promote wound healing. Penicillin, which had not been available when the first of these soldiers was treated, was also used freely. The tremendous measured blood loss in the second case emphasizes how dangerous it would have been to attempt to prepare this man for operation by plasma alone. The use of oxygen should also be noted.

As both of these histories indicate, the major problem of resuscitation of badly wounded men in World War II had to do with the management of shock. Shock is a disability of the circulatory system that parallels, and is caused by, loss of effective blood volume and hemoglobin. The major problem in all combat areas was how best to overcome these losses, or, more correctly, how to overcome them sufficiently to enable the patient to tolerate transportation to the hospital nearest the frontline where surgical facilities were available and where he could be prepared to withstand the surgery required by his special injury. For all practical purposes, then, an account of the resuscitation of wounded men in a combat area is principally a matter of blood-volume replacement. The history of resuscitation in the Mediterranean theater is epitomized in the innovations made in blood-volume replacement therapy and in their consequences.

The incidence of shock varied according to the echelon at which the patient was seen. One study¹ showed that about 2.5 percent of 2,853 wounded men were in need of special resuscitative measures on their arrival at an evacuation hospital in Italy, because surgical shock was established or impending. Two thousand two hundred and ninety-six of these men were injured on the Anzio beachhead, where, for tactical reasons, the evacuation hospital performed the functions ordinarily performed by a field hospital. Additional data supplied by the 2d Auxiliary Surgical Group and extended by material from the Office of the Surgeon, Mediterranean Theater of Operations, United States Army, showed about 2 percent of another group of wounded men to be in need of special resuscitative measures on their arrival at a field hospital. The incidence of shock on the level of the field hospital may therefore be assumed to have been from 2 to 2.5 percent.

GENERAL CONSIDERATIONS OF RESUSCITATION

The interval from the time the soldier was wounded until he had been restored to sufficiently good condition for his wound to be repaired was the most critical period he could undergo. In untreated patients, the balance during this interval was swung toward life or toward death by the operation of natural forces. The direction and extent of the swing could be influenced, in most cases, by the character and the timing of the treatment given the wounded man.

As has already been intimated, the first concern of those who had the care

¹ Beecher, H.; and Burnett, C.: Field Experience in the Use of Blood and Blood Substitutes (Plasma, Albumin) in Seriously Wounded Men. *M. Bull. North African Theater of Operations* 2: 2-7, July 1944.

of a freshly wounded man during this period was to do what was necessary to enable him to withstand transportation to a hospital. Their next concern was to prepare him to withstand the stress of emergency surgery. Everything else, even the question of his ultimate survival, was secondary to these immediate considerations.

The consequences of all wounds were cumulative. Pain often made rest impossible. Exhaustion was increased by emotional factors. Dehydration, which often was present before wounding, was increased by unusual fluid losses in sweat and vomitus, as well as by continuing hemorrhage and loss of plasma, with consequent reduction of hemoglobin and blood volume. If treatment was delayed, infection developed. These and other undesirable consequences were set in operation by the initial wound, and they continued unabated in the seriously wounded man until they were checked by surgery or interrupted by death. Resuscitative measures halted these effects temporarily, but such measures were merely palliative. Real relief from the grave consequences of the wound inflicted by enemy action could be accomplished only by surgery. After the wounded man had been received in a forward hospital, it is true that preparation for surgery was the immediate goal of resuscitation; but it was not an end in itself. In the broad general sense (p. 18) surgery was itself an essential phase of resuscitation.

These were not academic considerations. Any other concept of surgery would have led to an unfortunate separation between the activities of shock teams and surgical teams. The care of the wounded man had to be continuous, and his supervision had to be uninterrupted. Neither activity could be separated into compartments. The recognition of the essential unity of resuscitation and operation, though it was somewhat late in coming, was an important surgical advance in World War II.

That the operation itself should be an integral part of the resuscitative procedure was a perfectly logical concept. When internal hemorrhage persisted, for instance, there could be no resuscitation without surgery, and it was wasteful of both time and blood to attempt to raise the patient's blood pressure to normal before operation. The blood or plasma which was administered merely leaked into the traumatized regions and was wasted, while at the same time the patient was submitted to the hazard of an unnecessary number of transfusions. Surgery, with control of the hemorrhage, was the simplest and most effective way of accomplishing full resuscitation in such a case. Similarly, when extensive fecal contamination of the peritoneal cavity had occurred, or when leakage into or possible absorption from large areas of devitalized tissue was taking place, the shock and toxic manifestations which ensued could be terminated only by control of the causative factors at the source.

The best method of management in all such cases was to resort to surgery as soon as the patient had been brought to the desired stage of resuscitation (p. 18) and to continue resuscitative measures during the operation. This was the cardinal principle which, by a process of evolution, was finally worked out for the management of battle casualties during World War II. It does

not seem to have been emphasized or practiced to any considerable degree during World War I.

Differences in medical organization, evacuation policies, technical and human resources, and even the denotations and connotations of medical terminology differed so greatly in World War I and World War II that comparisons are, in general, neither useful nor valid. The following comparative data are, however, presented because the organization and mission of the 127th Field Hospital, which served in France in 1918, seem reasonably comparable to the organization and mission of the 33d Field Hospital, which served in the Mediterranean theater in 1943:

Over a 7-day period in 1918, the 127th Field Hospital admitted 256 wounded casualties, 41 of whom died before operation and 34 after operation.² The total case fatality rate was thus 29.3 percent and the surgical case fatality rate 15.8 percent. Over a 30-day period in 1943, the 33d Field Hospital admitted 297 wounded men, all of whom underwent operation, with 56 deaths.³ The total case fatality rate, which was entirely surgical, was thus 18.9 percent.

These figures, while perhaps not precisely comparable from a statistical point of view, illustrate very clearly the difference in concepts of management of severely wounded men in World War I and World War II. The significant point of the comparison is that, in 1918, 41 of 256 wounded soldiers (16 percent) died without operation, probably because they were never regarded as fit subjects for surgery, while in 1943, every one of 297 freshly wounded men was resuscitated and given his chance of survival through surgical intervention. The key to the difference is, of course, the emphasis placed upon preoperative resuscitation in World War II and the lesser emphasis placed upon this phase of medical care in World War I.

The problems of resuscitative therapy in World War II were greatly simplified once there was general acceptance of the concept that the cause of the deterioration of the status of a seriously wounded man was a reduction in the circulating blood volume because of loss of blood. Still further simplification occurred when the additional concept won general acceptance that, except for processes leading to dehydration, fluid loss from the circulation could be explained by loss at the site of injury alone. When profound anoxia was present, there was also some loss because of the general increase in capillary permeability associated with this condition.

The studies upon which these concepts were based⁴ showed in a useful and practical way the almost quantitative relationship between the blood loss after wounding and the degree of shock. This relationship had long been recognized, but it had lacked substantial proof up to this time. The proof was needed to outstride the storms which arise again and again from suggestions

² The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. I, pp. 109-110.

³ Annual Report, Medical Section, North African Theater of Operations, U. S. Army, 1943.

⁴ Medical Department, United States Army, Surgery in World War II. The Physiologic Effects of Wounds. Washington: U. S. Government Printing Office, 1952.

that the cause of shock is mysterious and is to be explained by toxins or by the breakdown of some vague but vital force.

This emphasis on the relationship between blood loss and shock, which was one of the outstanding features of the management of the battle-incurred injuries in World War II, did not in any way decrease the interest of medical officers in the problems of shock which remained to be solved. It also did not lead to any underestimation of the complexity of the mechanisms involved in the production of shock. It did, however, simplify the application of effective therapy, the chief component of which, as all the experience showed, was the prompt administration of blood in the quantities in which the individual wounded man required it.

All the available evidence pointed to blood loss, with the corresponding reduction of the circulating blood volume, as the explanation of the poor general condition of seriously wounded men when they were first seen in forward hospitals. All the evidence also pointed to the correction of these losses by replacement of the lost blood as the only method of improving the condition of these injured men and rendering them fit for surgery. The treatment of the local wound and the relief of pain and of mental distress were important, but not in comparison with the replacement of the lost blood. Furthermore, the more rapidly the losses could be corrected up to the point at which the deterioration of the man's condition could be checked, the better for him. These facts were demonstrated in every preoperative ward and every operating room from the beginning of the fighting in North Africa to the end of the fighting in Germany.

The stress of surgery for battle injuries.—The chief reason for the resuscitation of the freshly wounded soldier was to correct his impaired status. An additional reason was to prepare him for the strain to be imposed upon him by the operative procedure necessary to repair his injuries. How severe that strain was likely to be is suggested by the following data concerning the duration of typical operations, for the most part performed on the Anzio beachhead. The single large hospital area on the beachhead was near, and often in the midst of, the area of active combat. Many of the wounded were injured in the actual hospital area, and others on the adjacent road, which came to be known as Purple Heart Highway.

The duration (exclusive of the time occupied in the induction of anesthesia) of 130 typical major operations, chiefly performed in this hospital area, was as follows:

For 20 craniotomies in which the dura was opened, 109 ± 11 minutes.

For 10 laminectomies, 122 ± 7 minutes.

For 20 thoracotomies, 148 ± 14 minutes.

For 20 laparotomies, 117 ± 12 minutes.

For 20 vascular operations on the extremities involving ligation of the large vessels, 62 ± 5 minutes.

For 20 operations for compound fractures of the femur, including the application of the spica, 83 ± 8 minutes.

For 20 guillotine amputations of the femur, 69 ± 7 minutes.

These data are for consecutive, unselected cases. The operations were done by a number of different surgeons, all of whom were able and experienced. In spite of that fact, only wounds of the extremities could be handled surgically in approximately an hour. Operations on the head, chest, or abdomen without exception required about 2 hours or more. These operating times were typical of the experience in all forward areas. They do not differ materially from the operating times for similar operations in civil life. The strain of surgery of such magnitude, carried out over such long periods of time, could not have been withstood if the patients had not been adequately prepared in the shock tent to tolerate prolonged surgical stress.

At the beginning of World War II, it was the general impression that major surgical procedures in time of war seldom occupy more than an hour. Possibly this impression arose from the experience in World War I,⁵ in which operations on the extremities constituted a much higher proportion of the total operations than they did in World War II. As the figures cited show, this was not the experience in World War II, and these data symbolize the revolution in surgical thinking and progress which occurred between the world wars.

CHAIN OF EVACUATION

Since the status of a wounded man was influenced by the methods employed to remove him from the battlefield and transport him to a field hospital where he could be treated, a brief outline of the chain of evacuation is necessary in a discussion of resuscitation.

Resuscitation began at the battalion aid station, which was ordinarily located about 500 yards behind the line of combat, and which was reached, depending upon the wounded man's condition, by foot or by litter carry. Here, as well as in the collecting and clearing stations farther to the rear, the main objective of treatment was to make the wounded man transportable and to refrain from any procedure which would make him nontransportable. Therapy was therefore limited to such simple but essential measures as the control of hemorrhage; the application of splints and bandages, and of tourniquets if they were necessary (p. 35); the closure of sucking chest wounds; and the administration of plasma and morphine according to the indications of the special case.

Collecting stations, which were located about a mile beyond the battalion aid stations, were reached on foot, by litter carry, or by ambulance. As in aid stations, treatment was limited to what was absolutely essential. At times nothing more than inspection was required.

The division clearing station, which could care for approximately 100-150 patients at one time, was usually about 5 miles behind the collecting station. It was reached by ambulance. Here the patient's status was carefully ap-

⁵ The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. I, p. 5.

praised, and it was decided whether he could withstand the additional journey of several miles to the evacuation hospital, where necessary surgery could be performed, or should be taken at once to the field hospital for emergency surgery. The field hospital, which consisted of three platoons, with a capacity of 100 beds per platoon, was located adjacent to the division clearing station. It was staffed and equipped for major emergency surgery, and, equally important, for the care of patients for a maximum of 12 days after operation.

The patient's condition chiefly determined whether he should be removed to a field hospital for immediate surgery or transported farther to the rear for surgery later, but many other factors influenced the decision at the clearing station. It was necessary to take into consideration whether the road connecting the clearing station with the evacuation hospital was long or short, good or bad, and easy or difficult to traverse during a blackout. Conditions in the field hospital were also a consideration. This type of installation was invaluable when the nature of the injury or the status of the soldier contraindicated additional transportation, or when, for any reason, the time factor was important. The staff was usually competent, especially when teams from an auxiliary surgical group were assigned to supplement the regular staff. On the other hand, this type of hospital was frankly set up to handle emergency surgery. Because the medical staff was small, resuscitation was sometimes less rapid than in an evacuation hospital. Equipment was relatively limited, and the environment for postoperative care had some undesirable features. The field hospital was always far forward—near, or sometimes in front of, heavy artillery positions. Incessant cannonading made it difficult for the patient to get the rest he needed after operation, and limitations of personnel sometimes made postoperative care difficult, particularly during periods of heavy military action.

The patient operated on in a field hospital was eventually moved to the rear. Whenever possible, he was returned to duty directly from an army hospital. If this was not practical, he was moved, as soon as his condition permitted, from the evacuation hospital to a station or a general hospital. These were fixed installations, equipped and staffed for the performance of reparative operations designed to hasten healing, prevent irreparable damage or deformity, and expedite the wounded man's return to military duty. Resuscitation was seldom an essential phase of treatment in these fixed hospitals.

PREOPERATIVE (SHOCK) WARDS

In the course of World War II, numerous arrangements were tried out for the efficient management of wounded men to be prepared for surgery in forward installations. Some plans were unsatisfactory in their conception. Others were cumbersome and impractical. Experience eventually showed that, while details varied materially from one installation to another, some arrangement such as the following was the most generally satisfactory:

1. Shock wards or tents were set up, and all casualties in shock were

admitted to them, whether or not it was thought that they would require surgery.

2. Each shock ward was in charge of a single medical officer, who remained in the position for a matter of weeks, at least. Quick rotation of personnel merely promoted inefficiency.

In a field hospital the officer in charge of the shock ward was preferably chosen from the internists or junior surgeons on the staff. This was not a position for an inexperienced man, but the prolonged assignment of an experienced surgeon was also not wise; it inevitably led to discontent on his part and, eventually, to poor care of casualties. An assistant shock officer was trained to cover half of the 24-hour period, and at least 1 nurse or 1 aidman, or preferably both, were on duty at all times to assist the officer in charge. Twelve-hour periods of duty were not too taxing, even during times of heavy action, but longer assignments invariably led, within 2 or 3 days, to inadequate performance during rush periods.

In the evacuation hospital, a single medical officer was in charge of the shock ward, but an assistant was on duty with him at all times. The situation in this type of hospital differed from that in a field hospital. In a field hospital, all patients admitted were in need of resuscitation, but their number was limited. In an evacuation hospital, the incidence of shock was much lower, but the number of patients admitted during heavy drives made it necessary for two officers to be on duty continuously. Two additional officers were required to relieve these officers for half of the 24-hour period. At least 2 aidmen and 2 nurses were on duty at all times during rush periods. One of the officers on duty in the shock ward directed the flow of patients through it to the operating room, separating the patients who were in poor condition and in need of resuscitation from the others. The other officer directed resuscitative measures.

It is difficult to overestimate the importance of the function of the officer in charge of the shock ward. Toward the end of the war, some of the most experienced surgeons overseas took over the duty of its supervision.

3. The shock ward, when properly set up and administered, was a good deal more than a valve to regulate the flow of patients into the operating room, though this was a common and serious misconception of its function. Individual evaluation was necessary in every case. It was never possible to set up, on a mechanical basis, a relation between the optimum time for surgery and the number of casualties awaiting treatment, although such a relationship was inherent in the metered-flow point of view which there was sometimes a temptation to adopt.

4. The preoperative ward functioned satisfactorily only when the chief of the surgical service made frequent visits to it. It was part of his function, in collaboration with the shock officer, to set up priorities of operating time. As soon as possible, all patients awaiting surgery were assigned to specific surgical teams, and thereafter, as far as possible, the surgeon into whose charge the patient had been committed shared in all decisions concerning him, including decisions involving preparation for operation.

The plan just outlined insured continuity of attention for the wounded man, which was an integral part of good surgical care. Any system would have been fundamentally bad which allowed one group—the personnel of the shock ward—to carry a patient so far and no farther, after which his care was assumed by an entirely new group—the surgical team—whose personnel were completely unfamiliar with the man's previous status and therapy.

SHOCK: PREDISPOSING AND PRECIPITATING FACTORS

The treatment given wounded men in battalion aid stations, collecting companies, and clearing stations was generally good and often lifesaving. On the other hand, erroneous and inadequate therapy sometimes accounted for the poor condition of the patients when they arrived at forward hospitals. Among the common faults were overmedication, chiefly in the form of an excessive use of morphine (p. 41); the administration of too much plasma, or, less often, of too little plasma (p. 22); failure to recognize and close an open pneumothorax, or its inadequate closure; inadequate measures to control serious hemorrhage; transportation of wounded men with head injuries and injuries of the pharynx in the dorsal instead of the prone position; and failure to protect casualties properly during transportation. Under the last heading are included a wide variety of errors and omissions, ranging from careless splinting of broken bones to inadequate use of blankets, especially failure to place blankets under, as well as over, the patients in cold weather.

The pathologic processes set in motion when wounding occurred were basically responsible for the poor condition in which many wounded men arrived at forward hospitals. External circumstances, however, increased the number of those in precarious condition and in many instances precipitated, as well as aggravated, shock. The most important of these circumstances were exposure, incorrect treatment in forward areas, and delay in evacuation.

Exposure.—North Africa, Sicily, and Italy provided a wide variety of geographic and climatic conditions, including desert heat and mountain cold, high and low altitudes, and dry terrain and marshy land. It was over this terrain, some of which is among the most difficult in the world, that fighting was conducted by means of amphibious landings, isolated beachheads, rapid advances, and prolonged holding operations. Exposure under these conditions of combat was inevitable. Sometimes it led to heat exhaustion and sometimes to cold injury. It was usually associated with inadequate intake of food and fluid, and often with lack of rest.

Timelag.—The effect of delay on the wounded man's condition and the favorable influence of a brief lapse of time from wounding until operation were naturally appreciated from the beginning of the fighting in North Africa in November 1942. It was not, however, until the Italian phase of the war that it came to be generally realized that too much time was being lost before surgery, and that patients were being handled far too much, because of strict adherence to the formula of delays for inspection purposes along the line of

evacuation. These delays were defeating the efforts of the medical personnel, which were directed toward a single aim, that of presenting to the surgeon a patient who was as favorable as possible an operative risk.

As the plan of evacuation was set up, the patient was removed from the ambulance or inspected on the litter at each stop. Almost inevitably, the medical personnel attached to the special installation felt it incumbent on them to do something to him. This was to be expected. Because of shortages of experienced physicians, division clearing and collecting stations were necessarily manned by young men whose judgment had not yet been formed by experience, and who, in their eagerness to do their full duty, did not always distinguish between what was essential and what was superfluous. The time-lag was materially lengthened by these practices. When the men were critically injured, that fact was usually apparent. Additional inspections were not necessary to establish it. It was to the patients' best interest that they be handled as little as possible and be taken at once to the nearest hospital in which essential surgery could be carried out.

Possibly some patients with extremity wounds would have profited from being held at forward installations for an hour or two, but to teach corpsmen and inexperienced young doctors to identify those who would be helped by delay was simply not possible. The selection of the wrong patients for delay could be disastrous. Medical officers who did frontline work repeatedly stated that they had never seen a patient lose his life because he was evacuated too promptly, but all could recall instances in which lives had been lost because evacuation was too slow. This was sometimes unavoidable, but sometimes it was attributable to the cumbersome and time-consuming routine which had to be followed.

While reduction in the timelag from wounding to surgery was not the only factor in the reduction of morbidity and mortality, it was an important consideration. It influenced the salvage of extremities. It lessened deformity. It shortened convalescence. Sometimes it altered the outcome. The solution of the problem would have been the elimination of one or more stops along the line of evacuation, and it was repeatedly suggested that the system in use, which did not permit such bypassing, should be critically reviewed and modified in the light of experience. This did not happen. The system instituted at the beginning of the war remained essentially unaltered to the end.

In addition to the lowering of the patient's reserves by the delays on the battlefield and along the evacuation chain, rough handling was sometimes unavoidable in difficult litter transportation down mountain trails and in prolonged ambulance hauls over rough roads. These additional stresses, whether they were avoidable or unavoidable, could precipitate shock or increase it if it already existed.

APPRAISAL OF THE WOUNDED MAN

Although a certain routine of resuscitation was carried out in all shock wards, resuscitative measures were always applied on the basis of individual

needs, after a careful estimate (1) of the extent to which the casualty had suffered from his wounds and (2) of the therapy needed to enable him to tolerate immediate surgery in a field hospital or to withstand transportation to a hospital farther to the rear. Once he had reached the field or evacuation hospital, his reaction to the rigors of his journey, as well as his response to the resuscitative measures employed, furnished essential information concerning the additional treatment required to fit him to tolerate whatever surgery might be necessary. The first step was to rescue him from the state of shock in which organic damage could occur as the result of inadequate circulation. The next decision concerned the institution and timing of additional measures of resuscitation and of the operation itself—the operation, as already emphasized, being considered to be one phase of the resuscitative regimen.

The man's clothing (fig. 1) was removed completely before examination was undertaken or any resuscitative measures were instituted. Flagrant errors could follow failure to observe this elementary precaution. Its necessity can be shown by a single illustration. A soldier accidentally discharged his own rifle, wounding himself in the buttocks. The bullet reached its destina-

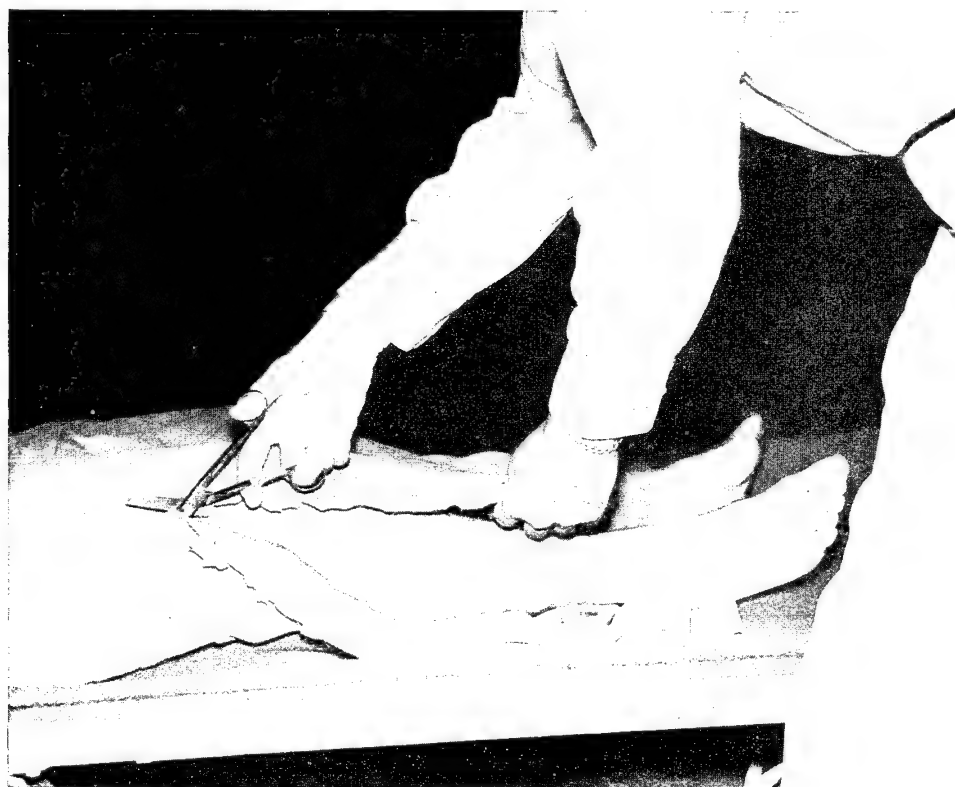


FIGURE 1.—Routine of early care of wounded man in forward hospital.
Removal of all clothing.

tion only after it had passed between his scalp and the inside of his helmet and then reversed its direction.

After the man's clothing had been removed, the litter was checked to make certain that blankets had been placed underneath him as well as over him. He was then completely examined, and a plan of management was drawn up. Basically, all patients were placed in two categories:

1. The patient with a slight wound, in good condition, was operated on as soon as there was space for him in the operating room, with due regard to the needs of those who were more seriously wounded.

2. The patient in poor condition was sent to the ward or tent set aside for men in shock and was given over to the charge of the shock team.

Patients in the first category required little of no special preparation for operation. For severely wounded patients in the second category, the preparation which they received for operation might make the difference between survival and death.

Classification of shock.—For practical purposes, the seriously wounded man was placed in 1 of 4 possible categories (table 1), depending upon the presence or absence of shock, and, if it were present, upon its degree. All of the following statements refer to the average patient:

1. The patient not in shock had a normal blood pressure and normal pulse. The temperature and color of the skin were normal. The pressure test, which showed a prompt return of color to the skin, indicated the integrity of the circulation. The patient might be thirsty, but his thirst was not abnormal. His mental state was clear, and he was capable of feeling depressed.

2. The patient in slight shock had a blood pressure about 20 mm. Hg below the normal level. The quality of the pulse was normal. The skin was cool. Its color was pale. The response to the blanching test was somewhat delayed. Thirst was not abnormal. The mental state was clear, but the patient was distressed.

3. The patient in moderate shock had a 20-mm. to 40-mm. Hg depression of blood pressure. The pulse volume was diminished. The skin was cool and pale. The response to the blanching test was unmistakably slow. The patient complained of thirst. His mental state was clear, but he was likely to be apathetic unless he was stimulated.

4. The patient in severe shock had a greatly depressed blood pressure, ranging from 40 mm. Hg below normal to an unrecordable level. The pulse was weak or imperceptible. The response to the blanching test was greatly delayed. The patient might complain bitterly of thirst, but otherwise he was apathetic and comatose and seemed to suffer very little distress.

While all of the observations listed furnished useful diagnostic information, the most important considerations in the appraisal of the status of a freshly wounded man were the trend of the pulse rate and the trend of the blood pressure. The trends were a great deal more significant than the levels at any given time. A rising pulse and a falling blood pressure nearly always indicated trouble

TABLE 1.—*Relationship of degree of shock and average blood loss in 67 patients with all types of wounds*

Degree of shock	Clinical observations							Average blood loss (corrected values in round numbers, in percentage of normal)	
	Blood pressure (approximate)	Pulse quality	Skin temperature	Skin color	Skin circulation (response to pressure, blanching)	Thirst	Mental state	Blood volume	Hemoglobin
None.....	Normal.....	Normal.....	Normal.....	Normal.....	Normal.....	Normal.....	Clear and distressed.	Per-cent 14	Per-cent 20
Slight.....	Decreased 20 percent or less.	.....do.....	Cool.....	Pale.....	Definite slowing.	.....do.....	.....do.....	21	30
Moderate.....	Decreased 20 to 40 percent.	Definite decrease in volume.	.....do.....	.....do.....	.....do.....	Definite.....	Clear and some apathy unless stimulated.	34	46
Severe.....	Decreased 40 percent to nonrecordable.	Weak to imperceptible.	Cold.....	Ashen to cyanotic (mottling).	Very sluggish.	Severe.....	Apathetic to comatose; little distress except thirst.	46	55

Source: Medical Department, United States Army, Surgery in World War II. The Physiologic Effects of Wounds. Washington: U. S. Government Printing Office, 1952, pp. 28, 56.

to come, especially if, in association with these phenomena, the skin of the patient who had been in a comfortably warm room felt cool to the touch.

It was essential that resuscitation teams understand the practical implications of shock as a dynamic and not a static state. The whole wartime experience proved that patients in shock did not remain in the same condition for any length of time. Their condition improved, or it deteriorated. This is why trends were sounder guides to therapy than absolutes. When the systolic blood pressure showed a constant upward tendency and had reached a level of 80 mm. Hg, the pulse rate usually showed a constant downward tendency, and the skin was usually warm and of good color. The patient was ready for surgery when these things occurred and could be operated on with safety long before the blood volume or blood pressure had been restored to absolute normal.

It was seldom difficult to recognize in the preoperative tent the casualty who was in poor condition. He seldom furnished any problem of identification. He usually carried obvious hallmarks of his status. The real problem was to identify the casualty whose condition, while still not critical, was deteriorating, and to identify him early enough to check the adverse forces at work in him. His prompt recognition was of benefit to him and also of benefit to his wounded associates. It meant economy of care, of materials, and of nursing and medical

effort. Because these things were expended only where they were needed, more rapid preparation of all wounded men for surgery was possible. This was indispensable if intolerable congestion in the preoperative ward was to be avoided. In the end, it meant the salvage of more lives. Experience repeatedly proved that it was far simpler from every standpoint to prevent serious deterioration in the condition of a wounded man than to rescue him from shock, once he had slipped into it.

The selection of patients who required close observation was made on clinical evidence: Their arms and legs were cool or cold. Their skin was pale. When it was blanched by pressure, the return of color was considerably delayed. The pulse was of rather small volume. The blood pressure might or might not be below normal levels. When it was below normal, resuscitative care was urgently needed.

Additional useful diagnostic points were the appearance of the wound; its character and extent; the evidence of considerable blood loss, whether internal or external; the evidence supplied by blood-soaked clothing; a history of exposure or exhaustion; and a history of delay in evacuation. Thirst was likely to be intense in the patient in critical condition; frequently it caused much suffering.

Except for those with head wounds, severely wounded men who were not in shock were usually clear mentally and often could give surprisingly accurate accounts of the events of wounding. Later, there was likely to be considerable amnesia for the early periods. In a sample of 201 badly wounded men who were not in shock when they arrived at a field hospital on the Anzio beachhead, 200 were in possession of their faculties.

In World War I, the absolute pulse rate, sweating, nausea, and vomiting were regarded as valuable signs and symptoms in the composite picture of shock. In World War II, they were not so regarded. Instead, they were thought to be related to the character of the wound or to psychologic factors, or to be reactions to the administration of morphine. The actual pulse rate could be influenced by too many factors to be of great value in itself in the estimate of shock, but its quality and its upward or downward trend were both most important. The degree of thirst and the patient's mental status, to neither of which much attention was paid in World War I (or is paid in civilian practice), were found to be extremely useful in the evaluation of the degree of shock in World War II.

One of the principles of resuscitation established in World War II was that if operation could not be undertaken immediately, as it frequently could not be when the flow of casualties was heavy and selection of cases had to be practiced, it was not necessary to achieve improvement beyond a rising blood pressure of at least 80 mm. Hg and a warm skin of good color. It was essential, however, not to permit regression, though it was best to withhold further resuscitative measures if the need for them was not evident. The patient who was merely kept in the satisfactory status described was unlikely to lose as much hemo-

globin if bleeding recurred as he would lose if plasma were given to raise the blood pressure higher than was necessary during the waiting period.

Laboratory data.—Laboratory data which could be secured in the field during the first hours after wounding were limited and were likely to be misleading. Estimates of the hemoglobin, hematocrit, and plasma-protein values showed little change immediately after wounding, when blood dilution had not yet taken place, though the information was of great usefulness in evaluating the needs of the wounded man during the postoperative period.⁶ Determination of the blood-volume level would have been of real assistance immediately after wounding, but the methods available for making this determination in World War II were too time consuming to justify their routine use in a frontline hospital. For these reasons, the simple clinical symptoms and signs described were used almost exclusively to gage the condition of the patient and the quantity of blood necessary to satisfy his individual need. If rightly interpreted, they proved entirely adequate for the purpose.

STABILIZATION VERSUS RAPID PREPARATION OF BATTLE CASUALTIES FOR SURGERY

Early in November 1943, at about the time the Volturno River was crossed and the fighting below Venafrò was heavy, a new point of view began to appear in the shock wards of the Fifth United States Army. In effect, it was that too much urgency was being exercised in the preparation of the wounded for surgery. At first, it was an entirely negative concept. After 2 or 3 months, and especially during the prolonged fighting before Cassino in the early months of 1944, it came to be expressed more positively that the wounded fared better when surgery was delayed for what was vaguely termed equilibration or stabilization. Exactly what was supposed to be accomplished by this period of delay was never clearly defined. The patient was merely supposed to be better for it.

There was, of course, some logic in this point of view. There was no doubt that a seriously wounded man who had suffered a period of exposure, who had been bounced in a speeding ambulance over rough roads for several hours, who had had little rest, and who sometimes was in great pain because of the effect of the trauma of transportation on his original wound frequently was the better after a period of rest. He was likely to arrive with a rapid, weak pulse and low blood pressure. After he had rested for 10 or 15 minutes, even if he had no other treatment, he usually looked better, his pulse improved in quality, and his blood pressure rose. These gains, however, were usually achieved in about 15 minutes.

The point of view of those who favored immediate operation and who opposed delay after the patient had been brought out of shock and after the downward trend of the blood pressure and the upward trend of the pulse had been reversed could be stated about as follows:

A wound sets in action several continuing processes. There is loss of blood.

⁶ See footnote 4, p. 7.

There is loss of plasma from serous surfaces and into traumatized tissues. Contamination leads to infection, and infection is progressive. All of these processes drain the resources of the seriously wounded man. They must be combated, and he must be supported, by the use of blood and plasma. It is a general principle that in any given case the smallest amount of blood and plasma should be used that is compatible with the patient's well-being. If surgery is delayed, larger quantities of these agents must be used to maintain him on an even keel than would be necessary if operation were performed earlier. This is undesirable from many standpoints, including the practical consideration that in World War II both blood and plasma were often in limited supply in the early part of the war.

On the basis of this reasoning, the advocates of early surgery contended that delay to achieve stabilization of the patient was without merit. They also based their reasoning on the analogy of perforated peptic ulcer in civilian practice. In that catastrophe, peritoneal contamination occurs, and the mortality rises sharply with the passage of time. Experience had shown that with the grosser contamination encountered in battle-incurred wounds, a rise in the case fatality rate when surgery was delayed could also reasonably be expected.

A deliberate test was undertaken in order to establish the proposition that as prompt surgery as possible was best for the patient and that delay for the sake of so-called stabilization did him no good and was often actually harmful.⁷ The management of 2,853 wounded men who were injured at Cassino and on the Anzio beachhead was conducted on the principle of operating as soon as resuscitation had been accomplished. In every instance, the patient was taken to the operating room as soon as the systolic blood pressure had reached 80 mm. Hg and was tending upward, the pulse rate was consistently falling and the quality of the pulse was improving, and the skin was warm and of good color. If additional blood was considered necessary, it was given in the course of the operation.

Comparison of the Anzio-Cassino experience in 1944 with experiences in field and evacuation hospitals below Venafrò and Mignano on the Cassino front in November and December of 1943 established the soundness of speedy resuscitation and prompt operation. In 1943, resuscitation of the seriously wounded to the point of operability often required 6 to 8 hours after the patients had reached the hospital. In 1944, even patients who were extremely bad risks when they were first seen were prepared for operation and submitted to surgery on an average of 2 hours and 20 minutes after wounding. The readier availability of whole blood in 1944 naturally had much to do with the reduction in the timelag as compared with 1943, but the change in the concept of the optimum time for operation played the major role in the improvement.

When the experience in the hospitals employed at Anzio and Cassino was compared with the theaterwide experience, other significant differences became apparent: In the Anzio and Cassino hospitals, each patient received an average of 1 unit of plasma, against an average of 3 units for the theater as a whole, and

⁷ See footnote 1, p. 5.

an average of 1,537 cc. of blood, against an average of 2,610 cc. for the theater as a whole. Transfusions averaged 3 per patient in the Anzio and Cassino hospitals, against 5 per patient for the theater as a whole. In other words, proper timing of resuscitation and surgery, in addition to cutting the time occupied by resuscitation in half, greatly reduced the amount of plasma and whole blood required for resuscitation. These are not trifling considerations. In spite of the generous provision of whole blood in the later part of World War II, it was always necessary to use it economically, and it will probably be necessary to use it even more economically in all future wars. The key to its economical use, without hardship to the wounded man, lies in the correct timing of resuscitation and surgery.

When the test of speedy resuscitation and prompt operation was undertaken in 1944, the concept was viewed with skepticism, and there was considerable discussion and disagreement before the conditions of the test were set up. The results, however, were so good from every standpoint that the concept of stabilization was gradually discarded and the concept of operation at the earliest possible moment came to be accepted as a satisfactory working principle. The time interval between wounding and operation was, on the whole, materially reduced by its adoption, but until the end of the war many medical officers felt that sufficient progress along these lines had not yet been accomplished.

The concept of prompt operation required an understanding of what could be achieved by resuscitative measures and what was impossible. The aim was not the restoration of the shocked patient to normal status before surgery was undertaken. That goal was unattainable. Those responsible for resuscitation had to face the realities of the situation and to decide what was desirable, what was possible, and what was impossible in the shocked patient. One thing that was impossible was the repair, in a matter of hours, of the organic damage produced by even fairly brief periods of low blood pressure. Many days would have been required for this in some cases. This amount of time could not be granted, nor was it necessary to take it in a man who was organically sound before he was wounded. All that was necessary was to make him safe for surgery. This was not always possible in patients with continuing internal bleeding or wide contamination of the peritoneal cavity. When resuscitative measures failed, in such cases, to produce their desired effects, the surgeon was faced with the necessity of undertaking operation in a patient in poor condition. This was a bold and critical decision, but many lives were saved in World War II because it was made affirmatively.

An important reason for not delaying surgery after the seriously wounded man had been brought out of shock was the readiness with which he could slip back into it. For reasons not altogether clear, a seriously wounded man or a man depleted by loss of blood could often be resuscitated to the point at which he was regarded as fit to tolerate the additional strain of surgery. If, however, operation were delayed and he were allowed to slip back into shock, a second resuscitation was always difficult, was often not as adequate as the first, and was sometimes not possible at all. All military surgeons, no matter

what their original point of view, eventually realized the importance of operating as soon as the patient had been brought to optimum status within a minimum period of time.

PLASMA

The difficulties experienced in resuscitation in the early fighting in Tunisia in World War II were in large part directly attributable to the completely mistaken concept, with which most surgeons entered the war, of the limits of usefulness of human blood plasma. These matters are discussed in detail elsewhere in this history,⁸ but no account of resuscitation in the Second World War would be complete without a brief account of that concept and how it was finally overturned.

The first recorded suggestion that plasma be used as a substitute for blood was made during World War I by Capt. Gordon R. Ward⁹ in a letter to the editor of the *British Medical Journal* in 1918:

There is abundant clinical and experimental evidence that it is not the corpuscles that are wanted, but the ideal fluid for keeping blood pressure at a proper level. * * * A man apparently dying from haemorrhage is not dying from lack of haemoglobin * * * but from draining away of fluid, resulting in devitalization and low blood pressure.

These remarks were followed by the eminently sensible suggestion that a trial of plasma should be undertaken and should be controlled by a comparable trial of transfusions of whole blood (and gum acacia). Plasma, however, did not become available in World War I, and Ward's suggestion seems never to have been carried out. Presumably, it stemmed from the belief that the methods of blood transfusion then available, with the hazards they involved, offered such great obstacles to the widespread use of blood in the resuscitation of battle casualties that the risks were not justified by the possible results.

The numerous studies made on plasma in the years between World War I and World War II are not pertinent to this brief account. The wartime enthusiasm for this agent began in 1939, when Tatum, Elliott, and Nessel¹⁰ recommended it as "an ideal substitute for whole blood in emergency treatment of shock and hemorrhage from war wounds." Their recommendation was echoed by numerous other observers in the subsequent months. The result, as DeBakey and Carter¹¹ commented, was that sound clinical judgments were pushed aside and the misconception became widespread that plasma was a complete and effective substitute for whole blood in the management of shock in the seriously wounded. This misconception, they continued, became so firmly entrenched in the minds of both administrative and professional personnel that it handicapped the organization and development of more effective measures for the management of shock.

With increasing experience in the management of shock in the fighting in

⁸ See footnote 4, p. 7.

⁹ Ward, G.: Transfusion of Plasma (correspondence). *Brit. M. J.* 1: 301, 9 March 1918.

¹⁰ Tatum, W. L.; Elliott, J.; and Nessel, N.: A Technique for the Preparation of a Substitute for Whole Blood Adaptable for Use During War Conditions. *Mil. Surgeon* 85: 481-489, December 1939.

¹¹ DeBakey, M. E.; and Carter, B. N.: Current Considerations of War Surgery. *Ann. Surg.* 121:545-563, May 1945.

North Africa, it became increasingly evident that plasma was by no means the physiologic substitute for whole blood which it had originally been believed to be. It was useful for bringing the wounded man out of shock and maintaining his blood volume during the period of transportation and immediately after his admission to the hospital, before a blood transfusion could be started, but its effects were transient. Moreover, it created a completely false sense of security, particularly if the surgeon in charge was of limited experience in combat surgery. Superficially, the patient to whom plasma had been administered might seem fully prepared for surgery. Actually, he was ill prepared. Often he could not tolerate movement, let alone anesthesia and other procedures which were part of the preparation for surgery. Their mere institution often caused him to fall back into shock. If operation were proceeded with under the circumstances, the result could be disastrous. In short, the early experience with plasma made it clear that whole blood was the only therapeutic agent which would prepare seriously wounded men for the surgery essential for the saving of life and limb.

The course of events might have been expected. Since plasma contains no hemoglobin, there was never any logical reason for believing that it would be a satisfactory substitute for blood in a wounded man who had lost a great deal of blood, as most seriously wounded men had. The use of plasma in these circumstances could be actually dangerous. The patient in poor condition because of blood loss, with a low blood volume and possibly a low hematocrit, could be placed in jeopardy if his blood (and effective vascular) volume was increased by plasma while his hemoglobin remained deficient. The blood volume might have been restored, but the meager quantity of hemoglobin available in the blood stream would have been correspondingly diluted and, within a brief time, would be further decreased because of the leakage permitted by restoration of the blood pressure. Many times in the early part of the Tunisian campaign, before the deficiencies of plasma for resuscitation were fully realized, a small additional loss of hemoglobin from renewed bleeding or in the course of operation was sufficiently critical to be disastrous. The patient's specious appearance of well-being promptly disappeared, and it became evident that, though he was apparently well prepared, he was completely unfitted to withstand the stress of anesthesia and surgery.

Although the misconceptions and errors that attended the early use of plasma in World War II are now widely recognized, they should not be permitted to obscure the remarkable value of this substance as a lifesaving agent. All through the war, it superbly fulfilled the role of supporting life until transportation could be accomplished to an installation at which whole-blood transfusion was feasible, as was not usually the case in battalion aid stations or division collecting or clearing stations near the frontline (fig. 2). By temporarily sustaining a seriously falling blood pressure and increasing cardiac output, it kept the patient alive long enough for more effective measures to be taken. When this concept of the possibilities and limitations of plasma became general and the stopgap character of plasma therapy was realized,



FIGURE 2.—Sicilian women and children watch from a doorway as blood plasma is administered to an American infantryman wounded by shrapnel in 1943. (U. S. Army photograph.)

the concept of resuscitation was correspondingly altered, and whole blood came to occupy its proper place as an agent of primary importance in the preparation of seriously wounded men for surgery.

It was not always easy to determine in a forward installation how much plasma a seriously wounded man needed and could safely be given. The initial dose, as a rule, was 500 cc. (2 units), and it was seldom necessary to give more than 1,000 cc. (4 units) during the 4 or 5 hours which usually elapsed before his admission to the field hospital. The objective was to give only enough plasma to raise the systolic blood pressure to about 80 mm. Hg and to keep the skin warm and the color good. The casualty did not suffer further deterioration when the blood pressure was at this level, nor did he sustain the needless and harmful loss of hemoglobin which might occur as a consequence of bleeding when the pressure was elevated more than was necessary to keep him out of shock. After he had reached a field or evacuation hospital, preparation for operation, as a general rule, required about 1 additional unit of plasma to 3 units of whole blood.

Burns.—Although plasma, in time, ceased to occupy the dominant place it

originally occupied in the preparation of wounded men for surgery, all through the war it formed part of the definitive therapy of burns. It compensated, indeed, for the chief deficit in that injury, since plasma is the fraction of the blood which is lost. Various rules were made for the quantities to be used, but the most common and most useful was that 2 units of plasma should be given in the first 24 hours of injury for each 10 percent of body surface burned, and that this regimen should be continued until hemoconcentration had been corrected. When laboratory examinations could be made, the rule was to give 100 cc. of plasma for each point the hematocrit was above the normal level of 45. If plasma-protein values were low, the quantity of plasma calculated to be necessary was increased by 25 percent for every gram below the 6-gm. percent level. Economies were effected in the treatment of burns, if the required quantity of plasma could be administered over the whole 24-hour period rather than in the space of a few hours, since, if more plasma than was needed was given at any one time, it was probably lost from the circulation.

In the management of burns, it had to be remembered that secondary shock might occur after the initial injury. This meant that anemia might be a secondary development in these cases and might require treatment with transfusions of whole blood.

WHOLE BLOOD

The shifting emphasis in the use of plasma and whole blood is evident in certain statistics from the Mediterranean Theater of Operations for 1943-45:

During the campaign in Tunisia, between 1 February and 31 March 1943, 972 casualties from the II Corps (34.3 percent of all wounded men requiring plasma) received an average of 320 units per thousand wounded.

Between 21 January and 28 February 1943, 101 of 431 seriously wounded II Corps casualties received plasma, the total quantity not being stated, and 31 also received blood transfusions.

In March 1943, 561 patients were given 97 transfusions in preparation for 741 operations in a field hospital.

In March 1943, at the 9th Evacuation Hospital, during the Tunisian campaign, 1,146 casualties were given 17 blood transfusions, 1:67.4. In April, 1,588 casualties received 54 transfusions, 1:29.4. In May, 397 casualties received 27 transfusions, 1:14.7.

During the first hundred days of the Italian campaign, which began 9 September 1943, the ratio of transfusions to battle casualties was 1:4.5. In January 1944, the ratio in all Fifth United States Army hospitals was 1:2.4. In March, a month after a blood bank had been established in the base area, the ratio was 1:1.9.

Between September 1944 and May 1945, 122 casualties in Fifth United States Army forward hospitals received, before operation, an average of 3.8 units of plasma per man, and 10 received, during operation, an average of 1.68 units per man. One hundred and twenty-seven patients received on the

average, before operation, 1,450 cc. of whole blood, and ninety-five received, during operation, an average of 1,160 cc. of whole blood. In other words, these patients, in contrast to those treated in Tunisia in 1943, received from the time of wounding to the end of operation an average of 5 transfusions of whole blood and an average of 3 to 4 units of plasma per man.

The use of blood and plasma varied, of course, among hospitals and casualties. During the first hundred days of the Italian campaign, the field hospitals of the Fifth United States Army, which cared for only one-thirteenth of the total number of battle casualties, used one-third of the available blood. Disproportionately large amounts were also required by individual severely wounded men. The establishment of the base blood bank early in 1944 made it possible, when necessary, to give as much as several liters of blood over a brief period of time to a single severely wounded man.

Blood was available in large quantities before the theater blood transfusion unit began to function. It was secured from local blood banks, from emergency donors, and on loan from the British. There was no comparison, however, between the convenience and safety of transfusion from the base blood bank and from these sources. These are not matters which can be easily shown in statistics or graphs.

Indications for blood replacement.—It has already been pointed out (p. 17) that the most helpful guides to the need for blood replacement were secured by simple clinical observation. To reiterate, they included the presence of blood-soaked clothing; the location and extent of the wound; the timelag since wounding; the rate and quality of the pulse, with particular emphasis on the trend; the level of the blood pressure, with particular emphasis on the trend; the state of the peripheral circulation, as indicated by the temperature of the skin and the speed of the response to blanching by pressure; the color of the mucous membranes; and the complaint (or lack of complaint) of thirst.

The paradoxical situation that the blood pressure might sometimes be normal when the patient was seriously depleted of blood led some physiologists remote from the battlefield to disparage the level of the blood pressure, even when it was low, as a useful sign in determining the need for blood. This was not a safe attitude, though, as has been pointed out, the upward or downward direction of the blood pressure, coupled with the quality of the pulse and its upward or downward swing, was far more useful than reliance upon arbitrary levels of pressure or pulse rate.

Quantitative blood replacement.—Studies made on the Anzio beachhead¹² may be taken as typical of the amounts of plasma and blood needed to prepare seriously wounded casualties for surgery. In this area, the most seriously wounded patients arrived at hospital installations about 4½ hours after wounding. The average ambulance haul was about 10 miles, over good roads. The comparatively short timelag justified deliberate appraisal of the patients, it being scarcely likely that an additional delay of a few minutes, added to the

¹² See footnote 1, p. 5.
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delay already experienced, would do them any serious harm. On the other hand, it had to be remembered that these men could not tolerate any extended delay, since the wounds themselves, the necessary handling, and the ambulance ride immediately preceding their entry into the hospital had probably reduced their reserves to their lowest point.

About a quarter of these most seriously wounded men studied in the Anzio beachhead hospital entered with no measurable blood pressure. From the time they were received in the hospital until definitive surgery was undertaken, an average of 1 unit of plasma (or albumin) and an average of 870 cc. of whole blood were given to each man in preparation for operation. During operation, about two-thirds of the patients received an additional 500 cc. of blood each, and about one-third received an additional 1,000 cc. of blood each. The quantities of blood administered by no means replaced the quantities lost; yet these men were apparently well prepared for surgery. None of them died in the course of operation. During the period of the investigation, the case fatality rate in the hospital involved was 1.48 percent, which was extremely low for surgery at this echelon. Finally, the surgeons who operated on these patients were unanimous in their opinion that preparation for operation was satisfactory.

All of the patients were prepared on the principles already outlined. They were considered fit for surgery when the systolic blood pressure was 80 mm. Hg and tending upward, when the pulse volume was good and the rate was tending downward, and when the skin was warm and the color good. When these criteria had been met, operation was undertaken without further delay. If additional blood was indicated, it was given in the course of the procedure. The medical officers responsible for the preparation of these patients considered that transfusion should be given on these principles for two fundamental reasons:

1. Transfusion is a potentially hazardous procedure, which should not be employed any more often than is absolutely necessary.
2. Economy in the use of whole blood was obligatory, because it was often in short or potentially short supply, particularly during periods of heavy action.

Certain other observers who did not share this point of view prepared patients in serious condition with quantities of blood which averaged 1,000 cc. more per man than these most seriously wounded men received at the Anzio hospital. The results of excessive administration were equally as good as, but no better than, the results accomplished in patients who had received smaller quantities of blood.

Technique of administration.—Except in serious emergencies, all blood given to wounded men was grouped and crossmatched with their own blood. Although this was not always easy under combat conditions, it was seldom impossible. The precautions obviously were necessary. Unless the greatest care was taken in the use of blood, accidents could nullify its value and place the patient in grave danger. Possibly, in the future, fuller information concerning low-titer O blood may reduce the necessity for grouping and cross-

matching in the field, but, at the close of World War II, these precautions were still essential for the safe transfusion of whole blood.

After 1,000 to 1,500 cc. of non-type-specific blood had been given to a bled-out casualty, a new sample of his blood was obtained for crossmatching. This precaution was repeated after the administration of every additional liter.

The speed with which blood was administered depended entirely upon how critical was the status of the man to whom it was being given, though certain general principles were also followed. If the patient's condition was considered to be desperate (that is, if the systolic blood pressure was below 60 mm. Hg), he was placed at once in the head-down position, with the foot of the litter elevated about 12 inches (fig. 3). A unit of plasma or albumin was administered while a transfusion of low-titer (iso-agglutinin titer of 1 : 64 or less) O blood was prepared. Blood was always obtained at the first venipuncture for grouping and crossmatching in subsequent transfusions; but in desperate cases time was not taken at the first transfusion for these precautions and they were sometimes omitted at the second also.

The first blood was often forced in rapidly by the use of a bulb from a blood-pressure apparatus attached to the air inlet of the blood flask. Oc-



FIGURE 3.—Routine of early care of wounded man in forward hospital. Elevation of foot of litter.

asionally, a second transfusion was also given by this technique. It was not a desirable method, for in careless hands it could, and did, cause fatalities from air embolism. As soon as the blood pressure had begun to rise, the speed of introduction of the blood was reduced, though the rate was promptly increased if signs of improvement were not maintained.

In critically injured patients, to be certain that the blood would flow in promptly, cannulas were introduced under direct vision after the vein had been cut down on. In emergencies, two or more transfusions were run in simultaneously through different veins.

Subsequent transfusions were given more slowly. When the systolic blood pressure had risen to 80 mm. Hg, the administration of 500 cc. over a 30-minute to 60-minute period was usually adequate. The same rate was adequate when the transfusion was given for prophylactic purposes, to guard against a fall of blood pressure which was probable or possible, but which had not yet occurred.

Reactions.—The transfusion of blood is always a complicated procedure filled with opportunities for human error. These opportunities, naturally, were greater in warfare than in civilian practice. As transfusions increased in number and the volume of blood used also increased, additional strains were placed on laboratory facilities and on personnel who dealt out the blood and checked it against the blood of the recipient.

The rapid use of large quantities of non-type-specific blood also opened the way to serious reactions, although their number, exclusive of those which followed the use of clearly mismatched blood, was on the whole remarkably low. Experiences in hundreds of hospitals with many thousands of transfusions showed that, with the proper precautions, the incidence of transfusion reactions need not exceed 3 percent. Reactions chiefly took the form of transient malaise, chills, fever, and urticaria. All of them could usually be traced to faulty preparation of the apparatus used. The chief errors were inadequate cleaning of equipment and delay of more than 2 hours in sterilization after cleaning. Fatal reactions were almost entirely attributable to urinary depression and uremia, apparently associated with renal damage arising from the deposition of free hemoglobin in the kidneys.

Blood transfusions in fixed hospitals.—Blood transfusions fulfilled the greatest need and had their greatest usefulness in forward (field and evacuation) hospitals, but they also had a wide field of usefulness in station and general hospitals, where reparative surgery was done. Many operations in these installations were major undertakings. An operation on a compound fracture, for instance, might require inspection of the fracture site, removal of bone fragments, and internal fixation of the fracture. Often fractures were multiple, as were the procedures undertaken to correct them. These and other operations were therefore often attended by a considerable blood loss, with resulting depression of the hemoglobin and hematocrit.

Experience in civilian surgery before World War II had demonstrated the importance of liberal blood transfusions in preparing the patient with

chronic sepsis for operation. In station and general hospitals, transfusions on this indication were fully as important as they were in civilian practice.

Finally, in spite of the liberal use of whole blood in the army area, many of the wounded, after undergoing initial wound surgery, arrived at general hospitals with profound reductions in hemoglobin and hematocrit values. In time, under the influence of an adequate diet supplemented by iron therapy, this type of anemia would undoubtedly have undergone spontaneous correction. Time, however, was lacking. There were a number of reasons in every case for getting ahead with the surgical program as promptly as possible, in addition to the general reason that the bed space was likely to be needed shortly for another wounded man. The sooner secondary surgery was done, the less likely was infection to occur or become established. The timelag between initial and reparative surgery was a very important period in wound management, sometimes equal in importance to the period between injury and initial surgery. Early closure of a gaping wound was imperative, if for no other reason than to prevent bacterial seeding of the raw surface during repeated dressings. It was also important to repair large defects by suture before fibroplasia stiffened the tissues and made approximation impossible without dead spaces.

For these various reasons, an extensive program of blood transfusion was developed in fixed hospitals. As a result, patients with low hemoglobin and hematocrit values were able to withstand secondary surgery promptly, while full advantage was taken of any favorable effect that the correction of anemia might have on the process of wound healing.

ALBUMIN

Albumin, like plasma, has the property of elevating a low blood pressure. This fraction of the blood exerts greater osmotic pressure than any of the other plasma proteins; 80 percent of the colloid osmotic pressure of normal plasma is accounted for by the albumin fraction. These and other observations had been made in the laboratory, and clinical trials had been conducted with albumin, before the United States entered World War II; and they were continued in Zone of Interior hospitals during the early months of American participation.

On the surface, it appeared that albumin would be an ideal agent for military use. As it was put up, it was ready for immediate administration, no reconstitution being necessary. Its small bulk and ready availability made it particularly attractive, in view of the limitations of space and weight which military necessities imposed on the transportation of supplies. It was remarkably stable. It could be administered in a third to a half of the time required for the administration of plasma. Finally, its administration was free from the risk of such sequelae as hepatitis and other infections. These various advantages suggested that albumin would be particularly useful in forward installations in a combat zone.

Certain disadvantages, however, had to be weighed against these advantages. Albumin is expensive in terms of the quantities of blood needed to prepare it. It was known, before the outbreak of the war, that its effects were likely to be transient. Since the albumin molecule is smaller than the molecule of the globulins, albumin presumably leaks out of the blood stream more rapidly. The antibodies naturally present in plasma are, of course, lost as albumin is separated out of plasma, and it was not known positively during World War II whether this loss was important. Finally, the use of undiluted albumin was dangerous in dehydrated patients.

For an adequate evaluation of its effectiveness, albumin should have been compared with plasma in a controlled study of its influence on the cardiac output and blood volume. This apparently had not been done in the various studies carried out in civilian hospitals before World War II, and the combat zone was not the place to pursue such an investigation. When, however, this agent first became available in Italy, in 1944, it was investigated in the first 200 patients in whom it was used, with the following results:

Blood-pressure determinations were made at 10-minute intervals in 61 men who had each received 25 gm. (1 unit) of albumin, and these values were compared with similar determinations in 89 patients who had each received 1 unit of plasma. The spread of the initial blood pressures, which were all below 80 mm. Hg, was comparable in both groups, as were the age, the nature of the wounds, the state of hydration, and the general condition of the patients. All observations could not be secured in all cases, but the available results were as follows:

In 19 cases treated with plasma, in which the average initial blood pressure was 49/21, the average pressure after 1 unit of plasma had been given was 88/52 in 15 cases. In 16 cases, the average minimum time required to achieve the maximum blood pressure was 19 minutes, while in 9 cases the average minimum time for the fall of blood pressure to begin was 29 minutes. In 40 cases treated with albumin, in which the average initial blood pressure was 47/22, the average pressure after 1 unit of albumin had been given was 83/53. In 34 cases, the average minimum time required to achieve the maximum blood pressure was 22 minutes, while in 19 cases the average minimum time for the fall of blood pressure to begin was 33 minutes. Comparative studies in other groups of cases in which the initial blood-pressure levels were higher gave results of substantially the same order as these.

These data were supplemented by observations of the general condition, skin temperature, and rate and quality of the pulse in the treated patients. All these observations, like the data on the blood pressure, had to be secured under the crude conditions of a combat zone, but clinically they added up to the conclusion that there was no demonstrable difference in the effects produced by the administration of 1 unit of albumin and 1 unit of plasma, although theoretically albumin was a much more powerful agent.

Plasma also had certain clinical advantages over albumin. The water in which it was administered was an asset in a wounded man with a tendency

toward dehydration. Concentrated albumin, on the other hand, depends for its effects on the withdrawal of fluid from the tissues into the blood stream; it therefore produces tissue dehydration. In a well-hydrated patient this was not a serious consideration. In a dehydrated patient it was, and in such cases albumin was administered in physiologic salt solution, usually in the amount of 2 units to the liter.

No severe untoward effects were observed from the use of albumin in the 200 patients studied. In 2 cases, a mild, transient urticaria was attributed to its use, and transient moist rales were observed in another patient with a thoracic injury. Albumin was always used with caution in patients with thoracic injuries, because of the possible risks of a sudden increase in blood volume.

The limited clinical trials carried out with albumin in the Mediterranean Theater of Operations led to the conclusion that its chief advantages were its small bulk and ready availability. These properties suggested that it might be useful in battalion aid stations and other posts difficult of access in a combat area, as well as in submarines and ambulance planes and for airborne troops. In other words, its usefulness seemed limited to places in which space and weight were at a premium. Whether it will be used for these purposes in a future war will depend upon the general principles by which military medical supplies are selected.

OTHER FLUID REPLACEMENT THERAPY

Numerous discussions of fluid-replacement therapy during World War II began with the injunction to give fluids by mouth if the wounded man would tolerate them. Instructions exactly to the contrary would have been more nearly in line with good medicomilitary practice. Fluids by mouth were usually definitely contraindicated before operation, especially if, as was almost always true, anesthesia was to be induced and operation performed within a matter of hours. An additional reason for withholding fluids during this period, aside from the fact that the man might have a gastric or intestinal perforation, was the fact that after wounding the gastric emptying time was always much longer than normal. Not infrequently, one observed the regurgitation of fluids and food which had been ingested as long as 10 hours earlier.

There were still other reasons for the restriction of oral fluids. They often precipitated vomiting, especially in patients who were already nauseated from the administration of morphine. Under these conditions, the net result of the ingestion of fluids by mouth was often a loss rather than a gain.

Furthermore, it became increasingly clear as the war progressed that one of the commonest preventable accidents on all surgical services was aspiration of gastric contents into the lungs. Sometimes the accident was the result of vomiting during anesthesia; very often it was the result of quiet aspiration, by the deeply anesthetized patient, of gastric contents forced into the pharynx as the result of surgical manipulations in the upper abdomen. However it

occurred, this was always a serious accident, and it could be fatal, especially if it was not realized that it had happened and if no steps were taken to correct it.

As a general rule, dehydration was not a special problem in recently wounded men in the Mediterranean theater, at least when the plan was followed of operating on them as promptly as possible after resuscitation had been accomplished. If a man complained of thirst, allowing him to rinse his mouth with water or suck a moist sponge would keep him more comfortable. These simple expedients kept the lips and mouth moist but introduced no fluid into the gastrointestinal tract. In the occasional case in which dehydration was sufficiently marked to require prompt correction, fluids were administered by the parenteral route, chiefly the intravenous route, in the form of physiologic salt solutions and dextrose solutions.

During periods of heavy action, when scores and even hundreds of wounded men were sometimes awaiting surgery in a single hospital, the maintenance of an adequate fluid intake might become a difficult problem because of the delay in treatment. Patients without gastrointestinal injuries were sometimes given fluids by mouth, with due regard to the time they were scheduled for operation. Others were given subcutaneous injections of physiologic salt solution or intravenous infusions of 5-percent dextrose in a similar solution. In no circumstances was more than a single liter of fluid given at a single infusion or injection, and the quantity administered was just sufficient to prevent dehydration.

At one period during the fighting on the Anzio beachhead, more than 300 patients were awaiting operation at the same time in one of the several hospitals in the area. Almost the same situation prevailed in other hospitals. It would have been a difficult task to keep all of these patients properly hydrated and otherwise cared for until their turns came for surgery. The situation was relieved, and the necessity of fluid replacement eliminated, by a shuttle of evacuation planes to the large hospital base at Naples, 40 minutes away by air, where there were facilities and personnel for prompt operation on all the patients.

The use of physiologic salt solution and dextrose solution was limited to the correction of dehydration. As blood substitutes, these solutions were not effective, and they could be dangerous. The elevation in blood volume and blood pressure which they accomplished was so transient as to be of little value, because the fluid promptly leaked out of the blood stream. If they were used in head injuries in large enough amounts to have a significant effect on the blood pressure, intracranial pressure might be seriously increased. Finally, their use in patients suffering from pulmonary injuries or in patients whose hearts were already subjected to stress might precipitate pulmonary edema or increase it if it were already present.

OTHER RESUSCITATIVE MEASURES

Relief of pain.—The control of pain under field conditions is discussed at length elsewhere in this volume (p. 46), but since it is a part of resuscitation general principles should be restated here.

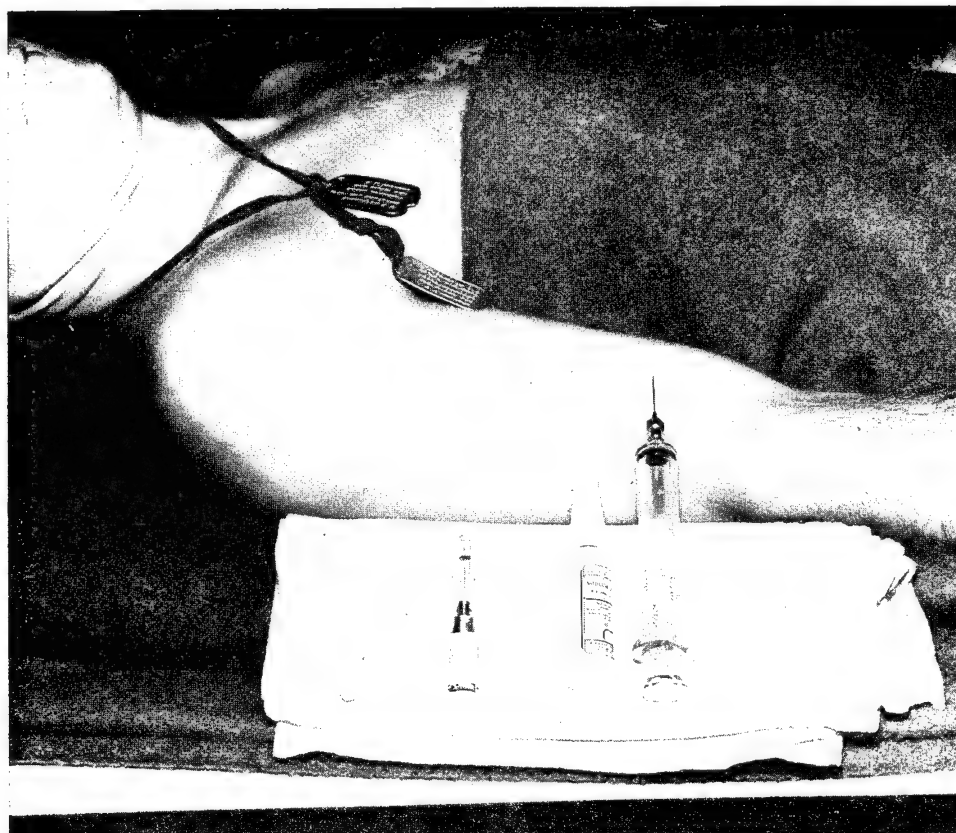


FIGURE 4.—Routine of early care of wounded man in forward hospital. Control of mental and physical distress by sedation (barbiturate) and administration of morphine.

Severe pain in badly wounded men was found to be much less common than it had previously been believed to be (p. 44). Excitement, fear, hysteria, and the restlessness caused by hemorrhage did not require morphine. They were best treated by small doses of a barbiturate (fig. 4), such as Sodium Amytal (sodium isoamylethylbarbiturate, p. 49). Many men reacted better to a cigarette and friendly reassurance than to a narcotic drug.

Although the principle was not always followed in practice, the only proper use of morphine was for the relief of severe pain. The ideal was to employ the smallest dose which would be effective. Large dosages caused nausea and vomiting and induced sweating, which led to undesirable losses of fluid. Most dangerous of all the effects of morphine was depression of the respiratory centers, which resulted in anoxia and was followed by an increase in shock. It was not possible to standardize dosages, but only occasionally, if at all, was a dose as large as 30 mg. (gr. $\frac{1}{2}$) necessary or indicated. A dose of this size was never repeated for at least 4 hours.

When small doses of morphine failed to relieve pain, the explanation was

often poor absorption of the drug. The peripheral circulation of wounded men with low blood pressure, particularly in cold weather, was often so sluggish as to delay the absorption of any drug which had been administered subcutaneously or intramuscularly. When relief of pain was urgent, the intravenous route was therefore the route of choice. Almost immediate relief could be secured by the intravenous injection, over a period of a minute, of 10 mg. (gr. $\frac{1}{6}$) of morphine, or of 15 mg. (gr. $\frac{1}{4}$) diluted in not more than 1.0 cc. of sterile water.

Proper preparation of the freshly wounded patient for initial wound surgery required not only that his pain be relieved but also that his psychologic and emotional problems be regarded as real and treated with sympathetic consideration (fig. 5). Understanding of these problems might, at the moment, seem less important than prompt surgical action, but disregard of them could leave psychologic and emotional scars which would be as harmful later in life as the results of poor surgery.

Management of the local wound.—The local wound in the preoperative period required little more than the control of hemorrhage and the application of splints. Control of hemorrhage was accomplished, in the order of prefer-



FIGURE 5—Routine of early care of wounded man in forward hospital. Spiritual care.

ence, by ligation of the bleeding vessel, insertion of a pressure pack, and the application of a tourniquet.

A tourniquet was necessarily employed when traumatic amputation had occurred or when a limb was badly mangled and was attached to the body by little more than shreds of tissue. It was applied just below the site of election for amputation and was not removed until the extremity had been severed.

When a tourniquet was applied to a limb in which there was a possibility of salvage, control of hemorrhage was frequently lifesaving, but the risk of ischemia and serious nerve damage was always present. When a tourniquet was applied under these circumstances, it was always placed as low on the limb as possible, and it was not loosened or removed except by a medical officer and not then until blood was already running into a vein. The risks of ignoring this precaution were first pointed out in the Mediterranean Theater of Operations, where it was shown that a man could lose his life from the additional blood loss which occurred when the tourniquet was loosened or removed casually. If, however, the man's condition was good, his blood pressure normal, the previous blood loss slight, and a medical officer available, then the tourniquet could be removed at half-hour intervals in an attempt to avoid additional tissue damage. Cooling of the extremity distal to the tourniquet was desirable, particularly when the environment was hot.

Temporary splinting of a wounded extremity prevented further damage and loss of blood and prevented or relieved pain. A badly applied splint could, in itself, cause pain and do damage. A frequent error early in the Tunisian campaign was to apply the Thomas splint without removing the shoe. Swelling invariably occurred distal to the wound and caused great pain, which was entirely unnecessary. The difficulty was overcome when it became the practice to unlace and slit the shoe if it was left on the foot in the application of a Thomas splint.

Position.—The quickest way of improving the wounded man's general condition on his arrival at the forward hospital was to elevate the foot of the litter about 12 inches (fig. 3) and permit him to rest in this position, with the head and upper part of the body lower than the rest of the body. In almost all cases which were not frankly hopeless, improvement was observed, with return of perceptible blood pressure, when this position was instituted, even before fluid replacement had been started. All badly wounded patients were therefore placed in the Trendelenburg position upon their arrival at the forward hospital, unless contraindications existed.

Pulmonary edema was one such contraindication. The head-down position was also used both tentatively and cautiously in patients with chest wounds, in whom it might produce respiratory difficulties, and in patients with head wounds. If, however, these casualties were in frank shock or had systolic blood pressures below 80 mm. Hg, the Trendelenburg position was employed under close observation and was maintained unless obvious signs of distress, labored respiration, or cyanosis required its abandonment. When once the systolic

blood pressure had risen to 80 mm. Hg, the head of the litter was gradually elevated; often as long as 20 to 30 minutes were spent in bringing the patient back to the recumbent position.

Conservation of body heat.—The wounded man frequently arrived at a medical facility cold and thoroughly chilled. Additional exposure to cold would naturally have affected him undesirably, but rapid warming was equally undesirable. Additional fluid loss through perspiration, increased metabolic needs, and dilatation of the protective vascular constriction were all possible and dangerous consequences of rapid, careless warming. The problem was to conserve the man's own body heat, not to increase it by artificial means.

Gradual warming was best accomplished by placing the patient in bed in a tent or ward at normal room temperature, with blankets under him as well as over him, while blood replacement was accomplished. Experience showed that this was an effective means of warming freshly wounded men. During the fighting before Cassino, although the ground was frozen hard and the nearby mountains were covered with snow, no other method had to be resorted to in any of the casualties observed by the surgeons in the mobile hospitals supporting the Fifth United States Army. Similar observations were made on the Anzio beachhead. Only occasionally, in fact, was artificial heat necessary. In May 1944, when the weather had become warm, one casualty with a rectal temperature of 84° F. was brought into an army hospital at Anzio. His temperature remained at this level for many hours in spite of the application of hot-water bottles to various parts of the body, and did not reach a normal level for more than 24 hours. This man had suffered a blast injury, with intracranial damage which was thought to have involved the hypothalamic area.

Emptying of the stomach.—Correct preoperative preparation included emptying of the stomach before anesthesia, to avoid the risk of aspiration of gastric contents (p. 31). This measure was desirable in all wounded men and urgently necessary if food or fluid had been taken after wounding or as recently as 2 hours or less prior to wounding. An additional reason for employing it was the observation that in some cases gastric dilatation might be great enough to interfere with the circulation. The mechanism of the circulatory improvement which was frequently observed after the stomach had been emptied was not clear, but there was no doubt of its occurrence. Possibly the greatly distended stomach interfered with proper filling of the heart. Another theory was that the vagal reflexes were involved.

Aspiration was occasionally necessary to empty the stomach (fig. 6), but as a rule it was better to induce vomiting. The largest size gastric tube that would slip down easily was introduced and was manipulated judiciously as it went down. Gastric lavage was seldom necessary and was always contraindicated if the location or manifestations of thoracic or abdominal wounds suggested that perforation of the esophagus or stomach might have occurred.

Oxygen administration.—Oxygen inhalations (fig. 7) were used freely for resuscitation during World War II, for the logical reason that they produced definite signs of clinical improvement in the form of a lowered pulse rate and

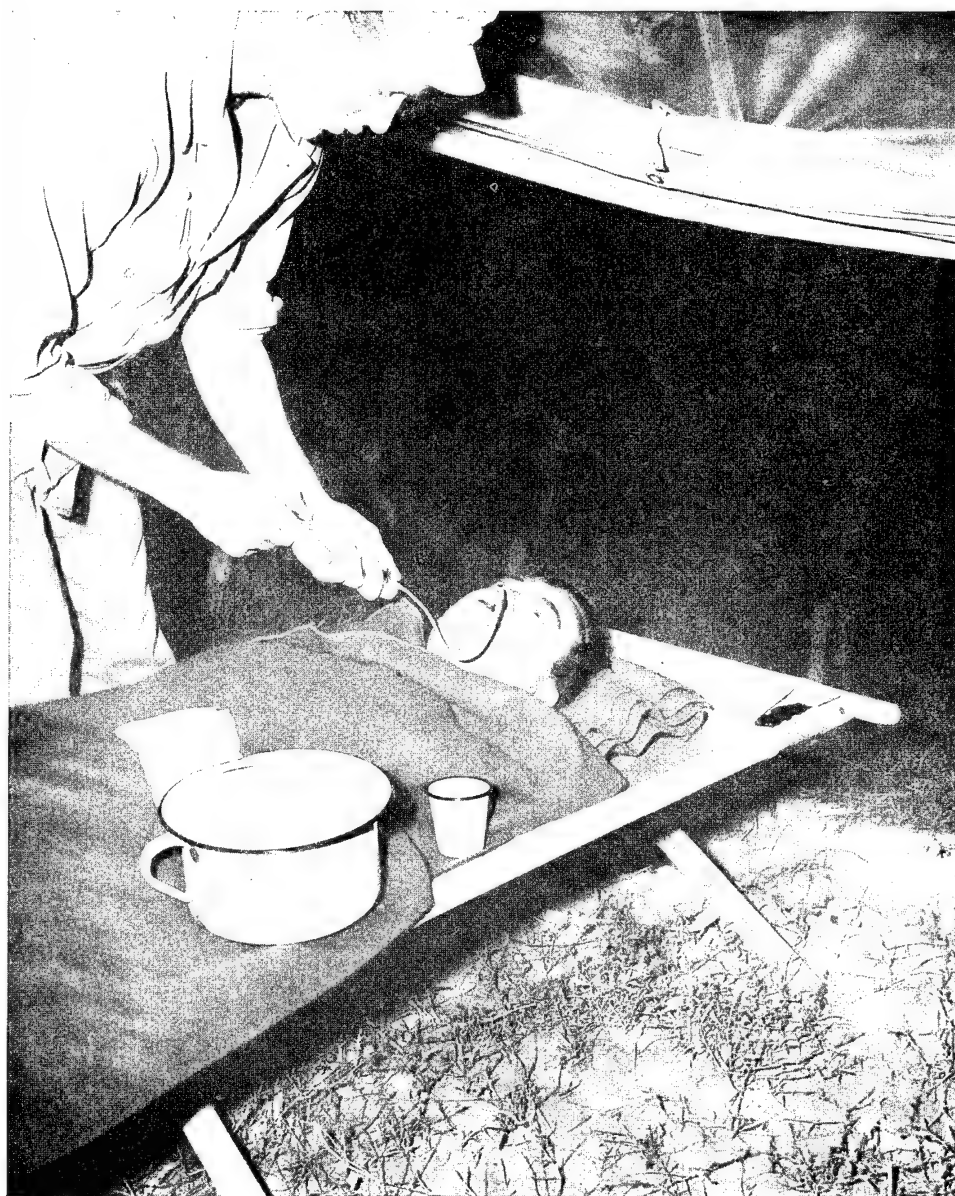


FIGURE 6.—Routine of early care of wounded man in forward hospital. Emptying of stomach.

a better coloration of the blood. Whether they were of lifesaving value in the management of severely wounded men was not established.

In the discussions of the use of oxygen, much was made of the fact that cyanosis will not appear as long as hemoglobin concentration is maintained at about a third of normal. Such low levels were not common in freshly

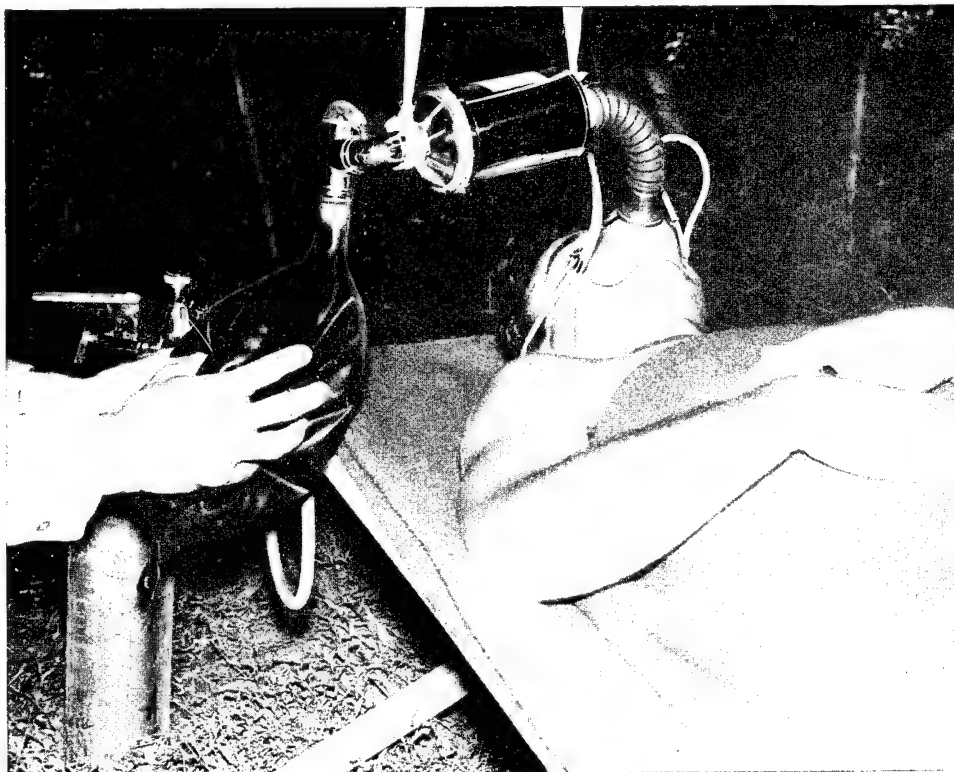


FIGURE 7.—Routine of early care of wounded man in forward hospital. Artificial respiration with oxygen.

wounded men. In a study of 37 severely wounded men filtered out from 2,853 casualties¹³ who, for the most part, had sustained their wounds on the Anzio beachhead, the average hemoglobin level was still 12.3 gm. percent at the end of 4½ hours after wounding, because sufficient time had not yet elapsed for complete blood dilution. The hematocrit varied. It was in the twenties in 5 of these cases, in the thirties in 16, and between 40 and 44 in 8. In the remaining case in which it was determined, it was 50.

Cyanosis was a more important and a more readily detectable sign of anoxia and oxygen deficiency than low hemoglobin levels. It was frequently overlooked, however, because of hasty examination under poor light in the preoperative tent. When it was present, an increase in the oxygen tension of the inspired air was undoubtedly desirable, though to what degree this objective was achieved in the field by the use of oxygen was open to considerable question. When oxygen was employed on any indication except respiratory obstruction or respiratory depression, it was used with the full realization that the patient's chief needs were an increase in the volume of the circulating blood and in the total quantity of circulating hemoglobin in the blood.

¹³ See footnote 1, p. 5.

Oxygen was most conveniently administered by nasal tube, after it had been humidified by being bubbled through a water column. The technique made it possible to service 4 or 5 patients from a single oxygen tank. A small catheter (12 to 14, French), well lubricated, was inserted into the nasal pharynx until the patient was observed to swallow a bolus of air. The tube was then withdrawn for half an inch and was firmly anchored to the cheek with adhesive tape. The correct distance of insertion was ordinarily about half an inch less than the distance between the ala nasi on one side and the lobe of the ear on the same side.

A gas flow of 4 to 5 liters per minute of 100-percent oxygen was usually well tolerated. If signs of oxygen deficit were not promptly relieved, higher concentration in the alveoli could be achieved through a closed system (fig. 7) with carbon dioxide absorption. The Beecher anesthesia machine proved satisfactory for this purpose.

Oxygen in high concentrations was not given continuously for more than 12 hours at a time. If, as occasionally happened, it was required beyond this time, the periods of administration in high concentrations were alternated with 12-hour periods during which the concentration was reduced to 50 to 60 percent. Care had to be taken to avoid gastric dilatation, particularly in unconscious patients.

Drugs.—Vasoconstrictor and stimulating drugs were of little or no value in the management of freshly wounded men and were almost never used. When they were employed, it was always in small dosages.

CHAPTER II

The Control of Pain in Men Wounded in Battle

Henry K. Beecher, M. D.

MORPHINE OVERDOSAGE AND POISONING

Early in November 1943, a curious phenomenon was repeatedly observed in the operating tents of forward hospital installations in Italy. Wounded men who were brought into the receiving wards in shock and thoroughly chilled all presented essentially the same appearance and clinical picture on their arrival. Some of them, after they had been warmed and had been treated by standard shock therapy, responded to it in the usual manner. Others, however, after receiving exactly the same kind of treatment, presented profound respiratory depression associated with pinpoint pupils, although neither of these signs had been present before resuscitation. These men, though they had not had morphine since they entered the hospital, were clearly suffering from morphine poisoning. In fact, in the absence of head injuries, and under the circumstances of combat, it was impossible to attribute their condition to any other cause. Alcoholism, chloral hydrate, and the barbiturates, all of which can produce a similar picture, could be excluded, for obvious reasons.

This phenomenon had been observed in patients who were burned in the Cocoanut Grove disaster in November 1942.¹ It had also been recorded in the civilian medical literature before it was observed in the Mediterranean Theater of Operations in the fall of 1943.

How frequently the syndrome of morphine poisoning occurred it is not possible to say. Often it was too severe to be overlooked. Occasionally it was fatal. On the other hand, it probably went unrecognized in many instances, because the manifestations were slight or subclinical. When it was serious, it might be misunderstood, but it could not be ignored. In the first 10 days of November 1943, morphine poisoning was recognized in several hospitals. On 11 November, it was discussed at the regular weekly medical meeting of the Fifth United States Army medical officers. Subsequently it was observed and commented on in all the hospitals in the theater.

A consideration of the circumstances of wounding and resuscitation offered an entirely reasonable explanation of what had happened to these wounded men. Early in November 1943, it was cold in the valley of the Volturno, where the fighting was taking place. It rained frequently, and

¹ The fire in the Cocoanut Grove, a Boston, Mass., night club, occurred on the evening of 28 November 1942. As a result of the disaster, 491 persons lost their lives. The author of part I of this volume was on the staff of the Massachusetts General Hospital, which received 114 of the fire victims within a period of 2 hours.

snow fell low on the mountainsides. If a man was not wet and chilled before he was wounded, he promptly became wet and chilled after he fell, even if he was picked up shortly after injury. Often he was subjected to further exposure in the course of a difficult litter carry to the receiving hospital. The result was impairment of the circulation in the skin and subcutaneous tissues. Sometimes the impairment was slight, but sometimes it amounted to almost complete cessation of the local circulation.

Under these conditions, it was not likely that the morphine administered as a first-aid measure on the battlefield would be absorbed. That it was not absorbed was proved by the fact that, in many instances, the injection of 30 mg. (gr. $\frac{1}{2}$), the amount put up in Army-issue syrettes, brought no relief of pain. A second, and often a third, injection in the same amount would therefore be given over a period of hours, each time with no perceptible effect. These wounded men were often described as "resistant" to morphine. When they were in good general condition and not in serious shock, an active peripheral circulation was promptly restored as they warmed up in the hospital, even if no other measure of resuscitation was employed. The restoration of the circulation caused the rapid, simultaneous absorption of all unabsorbed deposits of morphine, sometimes many hours after the injections had been made. If shock was present, and resuscitative measures in addition to warming were employed, the restoration of the peripheral circulation often led to dangerously rapid absorption. Either course of events was likely to be followed by morphine poisoning.²

It soon became evident that although morphine poisoning was an increased risk in cold weather, it was equally likely to develop, regardless of weather, in the presence of surgical shock, hemorrhage, or any other condition leading to, or associated with, a reduction in the peripheral circulation. It often became evident during anesthesia, in cases in which it was necessary to undertake operation before full resuscitation from shock had been accomplished. The chain of events was as follows: Ether stimulated the respiration. Peripheral vasodilatation then occurred. Morphine, which might have been injected as long as 8 or 10 hours earlier, was rapidly absorbed. When pinpoint pupils and profound respiratory depression developed before the surgical stage of anesthesia had been reached, induction was greatly prolonged, sometimes taking an hour or more.

Clinical manifestations.—Pinpoint pupils and slow respiration were the first manifestations of morphine poisoning. Respiratory depression led to anoxia, which was followed, in turn, by circulatory depression. These were the most serious consequences of overdoses of morphine, but less severe manifestations were frequent, and even small doses sometimes produced reactions which complicated treatment. A single injection of morphine might cause anorexia, nausea, and vomiting, which limited the intake of food and fluids by

² The possibility and dangers of morphine poisoning's developing in battle casualties, particularly under cold weather conditions, had been recognized and emphasized in the curricula for officer and noncommissioned-officer students at the Medical Field Service School, Carlisle Barracks, Pa., in the years preceding World War II.

mouth and increased the fluid loss in vomitus and sweat. The use of morphine even for brief periods was sometimes followed by severe constipation.

Management.—The realization that morphine intoxication might have a rather abrupt onset, sometimes many hours after the last injection, was essential in the diagnosis of morphine poisoning. Unless that fact was constantly borne in mind, treatment was likely to be delayed.

The first step in therapy was the application of a tourniquet proximal to the site of injection, to delay absorption. It was loosened at regular intervals. Body heat was conserved. Then the attention was devoted to the chief aim of therapy, which was to prevent anoxia. This was best accomplished by the administration of oxygen, supplemented by artificial respiration, if necessary. Oxygen was preferably given by means of a closed anesthesia apparatus, with carbon dioxide absorption, accomplished by intermittent pressure on the breathing bag. Atropine in doses of 1 mg. (gr. $\frac{1}{60}$) by vein, combined with ephedrine in doses of 30 mg. (gr. $\frac{1}{2}$), also by vein, was sometimes useful, the latter as a central stimulant and as a support against falling blood pressure. Hypertonic glucose solution was used intravenously for its diuretic effect, to hasten the excretion of morphine by the kidneys.

If coma developed, a gastric tube was inserted at once to eliminate the risk of aspiration of gastric contents. Pulmonary complications were guarded against by frequent changes of position. Supportive treatment was continued until it was apparent that the excess of morphine administered had been largely destroyed in the body.

INVESTIGATION OF PAIN IN WOUNDED MEN

The numerous instances of morphine overdosage and poisoning observed in Italy in November 1943, and in the succeeding weeks, suggested that the routine administration of morphine to wounded men, particularly in large doses, was not a safe procedure. The question also arose whether all wounded men experienced enough pain to warrant the risk attached to the use of this drug, especially in large doses.

To settle this question, a study was made of 225 patients who had sustained major wounds during the prolonged action on the Anzio beachhead and the Venafrò and Cassino fronts and, in a few instances, in southern France. The selection was as consecutive as the criteria permitted, the objective being to select patients with major injuries in certain categories who were clear mentally and who were not in shock when they were questioned. Ten of the two hundred and twenty-five men included in the original collection had to be dropped because they were unconscious or not clear mentally. A few others who had been in shock when they arrived at the hospital were not questioned until their status had improved. Included in the 215 patients were 50 with compound fractures of the long bones, 50 with extensive wounds of the peripheral soft tissues, 50 with penetrating wounds of the thorax, 50 with penetrating wounds of the abdomen, and 15 with penetrating head injuries. In most instances, the

wounds which formed the basis of selection (table 2) represented only the chief wounds. Most of the patients had multiple injuries.

The incidence of pain in the several categories of injuries was arrived at by asking the patients, shortly after their arrival at forward hospitals, several pertinent questions. These questions had been carefully framed, and great care was taken to see that each patient understood their meaning.

The first question was, "As you lie there, are you having any pain?" To it, 69 of the 215 patients (32.1 percent) replied that they felt no pain at all. The 146 patients who had complained of pain were then asked, "Is it slight pain, moderate pain, or bad (severe) pain?" In reply to this question, 55 (25.6 percent of the original 215) complained of slight pain, 40 (18.6 percent) of moderate pain, and 51 (23.7 percent) of severe pain.

These replies were not in accord with the long-accepted generalization that all extensive wounds are associated with severe pain and that the more extensive the wound, the worse is the pain. If it is possible to speak of such a subjective experience as pain in exact terms, it might be said that the generalization held in only about a quarter of all cases and failed partly or entirely in the other three quarters.

Patients who admitted to pain of any degree were next asked if they wished something to relieve it. The use of the term "morphine" was deliberately avoided. Experience had already shown that it was an unfortunate word to use in front of wounded men, who were likely to form the impression that if their condition was serious enough for them to need morphine they must, indeed, be quite badly off. A close parallelism naturally existed between the number of wounded men who complained of severe pain (51 patients, or 23.7 percent of the 215 in the series) and the number desiring medication for relief (58 patients, or 27.0 percent of the total number). In all, 157 of the 215 patients (73.0 percent) desired no medication, and 164 patients (76.3 percent) had no pain or slight to moderate pain. The results of this study seemed to show clearly that the routine injection of morphine was not necessary in forward hospitals.

In a great many of these patients, the striking absence of severe pain, and of any pain, could not be explained either by the amount of morphine received or the time at which it was given (table 2). Of the 51 who complained of severe pain, 5 had had no morphine since they were wounded. The other 46 had had an average total dose of 30.5 mg. and had received an average of 24.5 mg. in the most recent injection. Of the 157 who wished no medication when they were questioned, 32 had had no morphine at all. The other 125 had received an average total dose of 27.3 mg. The elapsed time since the last dose was essentially the same in both groups. It was therefore not possible to explain the degree of pain, or its presence or absence, on the basis of the amount of morphine given and the time at which it had been injected.

Only 1 of the 15 patients with penetrating wounds of the head complained of severe pain, in contrast to 6 of the 50 patients with wounds of the thorax, 12 of the 50 with extensive compound fractures of the long bones, and 24 of the 50 with penetrating wounds of the abdomen. Although there was little

TABLE 2.—*Analysis of pain sensation in 215 freshly wounded patients with major injuries*¹

Type of wound	Num- ber of cases	Age Years	Elapsed time since wounding Hours	Average total dose of mor- phine Mg. ²	Average last dose Mg. ²	Time since last dose Hours	Degree of pain experienced	Further relief by therapy desired	Essential data in patients with severe pain ²	Essential data in patients who desired no additional medication ²
Compound fracture of long bones.	50	24.8±0.9	12.5±1.3	27.0±1.5	22.6	7.0±0.8	19 none 12 slight 7 moderate 12 severe	11	12 patients. Total mor- phine 33.6 mg. Last dose 24.8 mg. 5.7 hours ago.	38 patients. Total mor- phine 28.1 mg. Last dose 7.4 hours ago.
Extensive peripheral soft- tissue wounds.	50	24.5±1.1	11.3±1.4	27.0±2.7	19.5	7.2±0.6	19 none 15 slight 8 moderate 8 severe	9	7 patients. Total mor- phine 33.0 mg. Last dose 22.8 mg. 9 hours ago.	30 patients. Total mor- phine 27.5 mg. Last dose 6.5 hours ago.
Penetrating wounds of thorax.	50	24.5±0.8	9.8±1.0	25.0±1.8	21.2	6.5±0.6	15 none 18 slight 11 moderate 6 severe	10	5 patients. Total mor- phine 23.9 mg. Last dose 19.0 mg. 6 hours ago.	30 patients. Total mor- phine 26.1 mg. Last dose 6.4 hours ago.
Penetrating wounds of abdomen.	50	22.7±0.6	7.2±0.7	20.0±2.2	25.0	4.8±0.7	7 none 5 slight 14 moderate 24 severe	27	21 patients. Total mor- phine 29.4 mg. Last dose 26.0 mg. 5 hours ago.	21 patients. Total mor- phine 30.1 mg. Last dose 5.1 hours ago.
Penetrating wounds of cerebrum.	15	25.1±1.4	7.9±1.4	19.8±4.2	19.8	6.2±1.5	9 none 5 slight 0 moderate 1 severe	1	1 patient. Total mor- phine 30.0 mg. (last dose) 14 hours ago.	

¹ Standard errors of the mean are shown. All doses of morphine are averages.² Patients who received no morphine are omitted from the appropriate calculations. All doses of morphine are averages.

difference in the amount of morphine received by the two groups of patients, there were four times as many complaints of severe pain in the group with abdominal injuries as in the group with thoracic injuries. Perhaps the explanation is the spill of blood and intestinal contents into the peritoneal cavity, as well as the role of infection. Be this as it may, these data supported the idea that, in forward areas, it was not necessary to give morphine routinely and that it would be wiser to administer it according to the needs of the individual patient.

RELIEF OF PAIN

Routine for administration of morphine.—It became apparent early in the Tunisian campaign that the 30-mg. (gr. $\frac{1}{2}$) amounts of morphine put up in Army-issue syrettes were too large for many patients, even when only single injections were used. Some observers attributed the difficulties which arose from overdosage of morphine and morphine poisoning to the fact that medical aidmen, for the first time in United States Army history, were being permitted to administer the drug. This was not the general opinion. It was repeatedly observed that medical officers were much more likely to be at fault in the over-generous use of morphine than were medical aidmen.

Throughout the war, there was a tendency in all theaters to overtreat wounded men with morphine in an endeavor to relieve pain. The situation in Italy began to improve when the Chief Surgeon, North African Theater of Operations, in December 1943, established the rule that morphine usually was not to be administered in more than $\frac{1}{4}$ gr. (half a syrette) single dose.³ In addition, a vigorous educational program was begun, and this endeavor, together with an increasing appreciation of the disastrous possibilities of delayed morphine poisoning, led to a sharp decline in the excessive use of the drug. It was about this time that the study just described was begun on the Anzio beachhead, and it promptly became clear that severe pain is much less common than was generally supposed in severely wounded men and that if morphine is used at all, it is not necessary to use it in large doses.

Eventually the following routine for the administration of morphine became fairly well standardized:

1. As a general rule, the amount injected in a single dose did not exceed 15 mg. (gr. $\frac{1}{4}$). In patients to be transported by air, in whom respiratory depression was particularly undesirable, the amount was reduced to 8 or 10 mg. (gr. $\frac{1}{8}$ or $\frac{1}{6}$). Maximum analgesic effects could be secured with these dosages, and the undesirable side effects caused by larger doses were seldom apparent.

2. Subcutaneous or intramuscular injection was employed when a gradual, prolonged effect was sought, but this route was avoided when the peripheral circulation was slowed by exposure, hemorrhage, shock, and other causes. Intravenous injection was then a better choice. It was also a better choice

³ Circular Letter No. 50, Headquarters, North African Theater of Operations, United States Army, Office of the Surgeon, 30 Dec. 1943, subject: Morphine.

when the immediate relief of pain was desired or when delayed absorption might prove harmful, as in impending shock. When 8 or 10 mg. (gr. $\frac{1}{8}$ or $\frac{1}{4}$) were given by this route, the full effect was achieved within a few minutes, and there was no possibility of delayed absorption. If the desired results were not obtained by the first injection, a second could be given, without risk, within 15 or 20 minutes. As a practical matter, it was almost never possible to administer morphine intravenously to a wounded man on the battlefield. Every circumstance conspired to make the continued use of peripheral injections necessary—the extra time which would be required for venous puncture, the urgent need for haste in the face of enemy action, the large numbers of casualties requiring treatment when combat was intense, the frequently collapsed state of the wounded man's veins, the poor physical facilities, and the inexperience of the nonprofessional personnel who gave the treatment. It was therefore the rule to give the injection on the battlefield intramuscularly (not subcutaneously) and to follow it by massage. The injection was made low enough on the extremity to permit the placing of a tourniquet above it to slow down the absorption rate if signs of morphine poisoning should develop. The site of the injection, the time it was given, and the size of the dose were recorded on the wounded man's emergency medical tag.

3. Morphine was not administered in the field to a patient who would be required to walk back to the battalion aid station, nor was it administered at the aid station to a man who would be evacuated to the rear at once as walking wounded. Its use under these circumstances was extremely dangerous. The man might become confused, lie down along the evacuation route, go to sleep, and suffer serious exposure or other untoward consequences. Another reason for withholding morphine from walking wounded was the accumulated evidence that nausea following its use was apt to be much more severe in ambulatory patients than in patients at rest in the recumbent position.

4. It was constantly emphasized to both medical officers and corpsmen that the only justifiable use for morphine was the relief of severe pain. Codeine or aspirin was to be used for mild degrees of pain.

5. In the absence of respiratory depression, morphine could be given in small doses to patients with head or chest wounds.

6. The routine use of morphine was avoided, unless it was required for pain, in the pre-anesthetic medication of seriously wounded patients, in whom anesthesia was usually easy to induce (p. 76).

7. The contraindications for the use of morphine were repeatedly emphasized. It was not to be employed for a sedative effect in nervous, manic, or hysterical patients. It was not to be used to allay fear, to promote sleep, or to control restlessness associated with hemorrhage. It was to be used in these circumstances only if pain was present. Otherwise, phenobarbital or pentobarbital sodium or paraldehyde, all of which were available, met the needs of the patient better than morphine. When pain was present in these conditions, the combination of small doses of morphine and a barbiturate often accomplished better results than large doses of either agent alone.

Morphine was absolutely contraindicated in patients in shock unless, as was highly unusual, severe pain was also present. The respiratory depression and the increased fluid loss in vomitus and sweat made its use in shock particularly undesirable. Morphine was used with great caution, if at all, in minor degrees of anoxia, such as were present in circulatory impairment. It was not used when the respiration was impaired by pneumothorax, hemothorax, or pleural effusion. It was not used when there was a mechanical obstruction of the airway or when a central depression existed. It was recognized as dangerous in hypothyroid patients or in those with low metabolism from other causes. Finally, it was used with great caution, if at all, in patients with liver disease, such as infectious hepatitis, since it is largely destroyed in the liver.

Relief of pain by other means.—Throughout the war, it was necessary to emphasize repeatedly to medical officers and corpsmen that morphine is not the only means of relieving pain. Regional nerve block, for instance, was sometimes useful, particularly in wounds of the chest. Either intercostal or paravertebral block controlled the pain of these injuries quickly and even dramatically, and, at the same time, by making it possible for the patient to breathe normally, this measure helped to restore pulmonary ventilation to normal.

Adequate support of the wound was another simple method of relieving pain. Swelling of the lower leg and foot usually occurred rapidly after fractures of the long bones of the extremity and was often extremely painful if the limb was left unsupported. Adequate immobilization of the wounded part whenever a skeletal injury was known or suspected to exist not only relieved pain but also prevented further local damage and militated against shock. Needless suffering could often be eliminated, without drugs, simply by unlacing and slitting the shoe in fractures of bones of the extremities.

The effectiveness of barbiturate administration, without morphine, is shown in the following case history:

Case report.—A husky 19-year-old soldier was brought into a forward hospital on the Anzio beachhead 5 hours after injury by a mortar shell. He had a wound near the vertebral column, which looked as if it had been made with a meat cleaver, through all the ribs from the 5th through the 12th. He was cyanotic and had lost a great deal of blood. The hemoglobin was 9.5 gm. percent, and the blood was not yet completely diluted. The patient was obsessed with the idea that he was lying on his rifle. He complained bitterly of pain and struggled constantly to get off the litter; three attendants were required to hold him on it. He appeared to be wild from pain, and his wound supported the idea, though examination in any adequate sense was impossible.

The patient had had no morphine for at least 4 hours, but it was decided, instead of giving him more, to give him 150 mg. (gr. $2\frac{1}{2}$) of Sodium Amytal by vein. Almost immediately after it was administered, he quieted down and went to sleep. His color improved strikingly, probably, at least in part, because the nasal oxygen tube, which he had repeatedly pulled out, could now be kept in place. His systolic blood pressure also rose from 60 to 80 mm. Hg. Before the barbiturate was given, all who saw him agreed that his condition was rapidly deteriorating. He began to improve as soon as he received it. The dose given could not possibly have controlled pain, and it seemed reasonable to assume that his manic state was not due to pain.

The patient could be roused, but he did not move of his own volition until he was taken to the operating room an hour later. In the meantime, a full examination had revealed that eight ribs had been cut in two. He had also sustained an open pneumothorax, lacerations of the lower lobe of the lung from the fractured costal end, and a laceration of the diaphragm. Catheterization, which had previously been impossible, revealed grossly bloody urine, which was found at operation to be due to a wound of the kidney.

Sodium Amytal was given to this patient, and to others treated in the same period, not from choice but because it was the only barbiturate then available. Pentobarbital sodium would have been used if it had been at hand. The small dosage of barbiturate employed in this case should be emphasized. Depleted, bled-out men, in shock, appeared extraordinarily sensitive to these agents, and the usual rule was that a single dose of 60 mg. (gr. 1) was the maximum amount permitted at any single injection.

THIRST

Three factors were usually of major importance in the suffering experienced by wounded men; namely, actual pain, mental distress, and thirst. Pain and mental distress were commonly encountered in men in good general condition, who were not in shock. In well-established traumatic shock, such suffering as was experienced was usually not from wounds or from anxiety, but from thirst. This was borne out by the men who were investigated from the standpoint of pain. They were not in shock, and they did not complain to any extent of thirst, of which men in shock usually complained bitterly.

It was not possible, of course, to alleviate thirst by oral administration of fluids in patients soon to be anesthetized. Its correction required restoration of the depleted blood volume, which could best be achieved by intravenous fluid therapy. While the fluid balance was thus being restored, the patient's lips were moistened frequently, and he was permitted to rinse out his mouth. In view of the amount of suffering which can be caused by thirst, it is remarkable that so little attention has been paid to it and to measures for relieving it.

PSYCHOLOGIC PREPARATION FOR OPERATION ⁴

A consideration of certain psychic and emotional factors may throw some light upon the relatively small incidence of severe pain after wounding, as evident in the investigation conducted in the Mediterranean theater. The psychologic preparation for operation was quite as important as the physical preparation, and it is unfortunate that under the stress of combat conditions less attention was paid to it than it should have received.

Most wounded soldiers were young, and their reactions were correspondingly immature. The natural emotional instability of youth had been exaggerated by the harrowing experiences they had undergone. They had suddenly been released by their wounds from an exceedingly dangerous environment filled with fatigue, discomfort, fear, anxiety, and real danger of death.

⁴ The wide experiences of Chaplain (Maj.) M. I. English and Maj. Douglas Kelling, MC, were drawn upon for this section.

Many men in the confusion of the first hours after wounding became euphoric. Euphoria was probably more often an early postoperative manifestation, but it was by no means unusual to observe it in the preoperative ward. It was probably based on the overwhelming realization that, no matter what happened in the future, the war was suddenly over for this particular wounded man. His wound, in effect, had furnished him with a ticket to the safety of the hospital. With that thought, he overcompensated and became euphoric, with the further result that this emotional release blocked the pain which he might otherwise have felt. If there are other, more valid, explanations for the absence of pain in the study conducted in Italy, they did not become apparent.

The early euphoric reaction was often followed by profound depression. Psychiatrists repeatedly commented on this sequence, which was particularly notable in men who required amputation.

Before wounding, as has just been mentioned, the soldier had lived under circumstances of anxiety and emotional stress. He had been grieved by the wounding and death of friends. He was naturally fearful for his own safety. These emotions were likely to be exaggerated by the sights and sounds of prolonged combat, coupled with the physical discomforts of exposure to bad weather, inadequate food and fluid intake, loss of sleep, and exhaustion, as well as pain. Then, in addition to these considerations, the wounded man suddenly had to face the consequences of his own wound: If his arm was injured, would he lose it? If there was blood about the genitals, would he become impotent? This was a possibility about which there was always great anxiety. Would he lose his sight? Would he be disfigured? Would the chest wound or the abdominal wound he had sustained kill him?

This inner turmoil was manifested in various ways. Sometimes the man lay quietly, seemingly asleep, until a casual question brought out, in a rush of words, the indications of great mental stress. Other men showed their turmoil by restlessness or, occasionally, by manic behavior. Patients who were described as writhing in pain and who had been given large doses of morphine were sometimes found to be suffering from restlessness caused by cerebral anoxia, or from excitement caused by fear and apprehension, which could be overcome by sedation with barbiturates. Morphine was never indicated in these circumstances.

Psychiatrists were always in too short supply and were too much occupied with other matters to participate very often in the preparation of the wounded man for surgery. Psychologic preparation for operation therefore had to be the concern of other members of the medical staff and the chaplain. Medical officers carried heavy responsibilities, and in their involvement in them, they were sometimes inclined to disregard mental and emotional considerations in the wounded men under their care. It is unlikely that any deaths occurred as a result, but only the future will reveal what effect disregard of these considerations will have on these men's later lives. In any preoperative ward, thoughtful discussion of their condition with wounded men showed how important these

considerations were and how much needless suffering was caused when they were ignored.

The surgeon's first approach to the wounded patient was the most important. Ideally, he represented the trusted family physician. He was cheerful but never casual. His confidence in his own ability, which could further be built up by the chaplain, was transferred to the patient.

Consultations were always avoided in the patient's presence; they were likely to make him think he was worse off than he really was. His questions were answered carefully. Hope was held out in all correctible lesions. If the lesion was not correctible, the man was told frankly that he might have to lose an arm or a leg. He was assured that everything possible would be done to save the limb, and it was stressed that many men who had undergone similar experiences had been able to live normal, useful lives afterward. Whenever possible, the patient who needed an amputation was told of it before operation; failure to do so was likely to lead to lack of confidence in his future care.

Certain uncorrectible lesions, such as great facial disfigurement, loss of the genitalia, and paraplegia, were difficult to discuss. If the outcome could not be foretold, it was usually best to assure the man that everything possible would be done for him. The proper psychologic management of patients in this group presented a fruitful field for study, which was not gone into during World War II.

Neglect of these emotional problems also had military implications. The patient's permanent outlook on his Army duties might be powerfully and lastingly influenced by it. The casual, lighthearted statement by a medical officer that the patient, now that he was wounded, could go home, could do untold damage if it later proved untrue. It might be impossible, in fact, to reestablish in the healed patient the qualities of a good combat soldier. If a patient's condition was called exhaustion in his hearing, a good response to treatment was likely to be obtained. If it was called shellshock, he was likely to be incurable. The early hours after wounding were thus important for establishing in the patient a point of view that would facilitate his early return to duty.

The chaplain.—The commanding officer or the medical officer directly in charge of a wounded man was often inclined to appraise the value of the chaplain in terms of his own need, or lack of need, for religious support, rather than in terms of what the man himself might want. A fair minority of seriously wounded men were not at ease mentally until they had received spiritual attention. They suffered without it. It was an error for the medical officer to take the position that there was nothing the chaplain could do for a wounded man that a good physician could not accomplish. It was frequently observed, in fact, that the physician who assumed that he was good at handling such matters was actually very bad at them.

The enlisted man, in the combat zone, at least, was often more religious than might be expected. Even if he had grown away from his religion through carelessness, he, like the man who had continued to follow his religion, had confidence in the help the chaplain could give him, and he wanted it in this

crisis. Medical officers presented a different problem. Members of this group sometimes actively rejected religion for intellectual reasons, or felt superior to it on grounds of logic, or were merely indifferent. The best medical officers, however, were the ones who recognized in an able chaplain an intelligence equal to their own and who acted on the assumption that he had something to offer the wounded man, even if they could not put into words just what it was.

The chaplain who cared properly for the wounded needed a great deal of understanding and sympathy. He had to grasp the fact that the soldier had been torn from his familiar life and thrown into a strange milieu, where old standards of conduct were ignored or were deliberately escaped. Animal spirits might have led him into adventures that his early training and standards had taught him were wrong. Then he was wounded and suddenly faced with the possibility of death. He was frightened and spiritually confused, and the chaplain who could deal with his feelings of guilt and who could help him to acquire serenity was heartily welcomed.

It was essential, of course, that the chaplain be brought into the case matter of factly. It was a serious error to project religious care abruptly upon the wounded man, no matter what his beliefs. Invariably this mode of approach convinced him of the gravity of his wound, whether or not that was true. On the other hand, the presence of the chaplain was essential to wounded men whose religious faiths embodied a ritual of departure. To men of these beliefs, the administration of the Last Sacraments was not alarming. Experienced chaplains and experienced psychiatrists alike insisted that it was sometimes desirable to tell a wounded man that he was going to die. Even medical officers who did not share his religious beliefs often saw anguished hope give place to tranquillity when once the wounded man knew that for him the end was not far away.

CHAPTER III

Anesthesia for Men Wounded in Battle

Henry K. Beecher, M. D.

The selection of an anesthetic agent, the technique of administration employed, and the competence of administration of the anesthetic are matters of the greatest importance in the peacetime practice of surgery. They are doubly important in the surgery of combat-incurred injuries. The relationship between anesthesia and shock is particularly close in operations performed upon seriously wounded men, not only because of the frequent occurrence of shock after wounding but also because, if it is not already present, anesthesia can be, and often is, a precipitating factor in its development. It is entirely possible for an unwisely selected or incompetently given anesthetic to precipitate such profound shock in a wounded man whose status was previously not unsatisfactory that a compensated circulatory system is transformed into a state of decompensation. All of the mechanisms of this process, although not yet fully clarified, were sufficiently well understood when the United States entered World War II for the considerations which determined the acceptability or unsuitability of available anesthetic agents to be clearly comprehended and to be translated into appropriate action by all anesthetists who cared for wounded men.

HISTORICAL NOTE

It is indicative of the lack of emphasis placed upon anesthesia in World War I that the section dealing with it in the official history was written by a surgeon, Col. George W. Crile, MC.¹ The specialty was not represented in The Surgeon General's Office, and consultants in anesthesia were not appointed for service either overseas or in the United States. Few of the points of view presented in the summary which follows could be substantiated at the beginning of World War II, but the material is presented because of its historical interest.

Nitrous oxide-oxygen anesthesia.—In the first year of the First World War, according to the official history, the paramount value of nitrous oxide-oxygen anesthesia was clearly demonstrated by American anesthetists attached to the Western Reserve University unit, which worked at the American Ambulance at Neuilly, France. Satisfactory anesthesia could be obtained with this agent in operations on seriously wounded men, whatever their degree of exhaustion. When the unit returned to America, one of the nurse-anesthetists

¹ Crile, George W.: Anesthesia. In *The Medical Department of the United States Army in the World War*. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1, pp. 166-184.

remained in France, at the special request of French and English medical officers, to give instruction in the technique of nitrous oxide administration.

The early enthusiasm for nitrous oxide-oxygen anesthesia continued for a considerable period.² Conclusions adopted by the Inter-Allied Surgical Conference at its second session, in Paris, in 1917, reaffirmed the confidence felt in it by the delegates present, who represented England, Belgium, France, Italy, Japan, Portugal, and Serbia. It was the consensus of the conference that this form of anesthesia (combined with local anesthesia) was the method of choice in traumatic shock, in amputations, and in gas gangrene. Ether was the second choice. Local anesthesia was preferred for cerebral injuries. Chloroform was regarded as dangerous, and spinal anesthesia was reported as giving varying results.

When Base Hospital No. 4 (the Lakeside unit), which was the first base-hospital unit of the United States Army to be called into service after the United States entered the war, left for France, it was equipped with what was assumed to be an adequate supply of nitrous oxide and with sufficient apparatus for its administration. During the summer of 1917, surgeons of the unit had opportunities at a British base hospital in Rouen and at British casualty clearing stations in Flanders to test the comparative advantages of nitrous oxide, ether, and spinal anesthesia. English and French medical officers became interested in securing adequate supplies of nitrous oxide, and it was soon evident that what the Lakeside unit had brought over would not be sufficient for its own needs. The English supply was totally inadequate. The difficulty was solved by the appropriation by the American National Red Cross of funds for the construction of a plant for the production of nitrous oxide. Various delays ensued, and it was not until the early summer of 1918 that the plant was in operation in France and was manufacturing the gas at the rate of 125,000 gallons every 8 hours.

It was generally acknowledged that nitrous oxide-oxygen anesthesia gave less satisfactory muscular relaxation than either ether or chloroform, that it required expensive and cumbersome apparatus for its transportation and administration, that it cost more than other anesthetics, that it was technically the most difficult to administer of all the anesthetics then available, and that it was dangerous in inexperienced hands. These disadvantages, however, were thought to be outweighed by its advantages, including the following: It was quick in action and pleasant to take; recovery was immediate, without nausea; food could be taken soon after recovery; transportation was possible soon after recovery; less nursing care was required; such complications as bronchitis, pneumonia, and nephritis did not follow it; and, finally, nitrous oxide was thought to be strongly protective against the shock of surgery. It was particularly favored for short operations but was regarded as equally suitable for long

² Surgery at the Base. Compilation of Responses by Base-Hospital Staffs to Questionnaire Sent Out by Research Committee. Questionnaire Prepared by Brig. Gen. J. M. T. Finney and Col. G. W. Crile. Compilation of Responses Made by Maj. T. W. Burnett. War Med. 2: 1281-1350, February-March 1919.

ones. If it did not bring about sufficient muscular relaxation in abdominal operations, it could be supplemented by regional anesthesia.³

Ether and chloroform.—In the chapter on anesthesia in The Medical Department of the United States Army in the World War, ether and chloroform are discussed under the same general heading.⁴ Both were thought to contribute actively to shock and exhaustion. Both, if given for any length of time, were thought to cause cytologic changes in the cells of the brain, the liver, and the adrenal glands identical with those resulting from other causes of exhaustion. Patients who did well under ether anesthesia were said to do poorly later. It was believed that ether tended to cause bronchopneumonia, especially in abdominal surgery performed in the winter; to be unsuitable in infections because it diminished, and even temporarily abolished, phagocytosis; to be unsuitable in shock because of its tendency to cause a fall in blood pressure; and to be responsible for a rather large diminution in the reserve alkalinity of the blood.

Spinal anesthesia.—The tendency of spinal anesthesia to produce a fall in blood pressure was recognized in World War I, the decrease being most notable in patients whose blood was greatly diluted and whose hemoglobin was low. On the other hand, this was stated to be the type of patient most in need of protective nerve block. The practice was to attempt to overcome the fall in blood pressure by a preliminary blood transfusion. The disadvantage of psychic shock, arising from the sights and sounds of the operating room and the patient's awareness of what was happening, was recognized, but it was pointed out that these difficulties could be overcome by the administration of morphine or, better, by very light nitrous oxide-oxygen anesthesia or partial ether anesthesia.

Spinal anesthesia was believed to be of special value when lesions in the air passages rendered inhalation anesthesia inadvisable or when the prone position was necessary because of the nature of the wounds. It was granted that it was time consuming to administer, and its use in rush periods was therefore not thought to be justified, on the ground that it would work a hardship to other patients awaiting operation, who might be subjected to the risk that anaerobic contamination could become gas gangrene. The statement that one of the advantages of spinal anesthesia is that it does not require a trained anesthetist to give it has a curious sound to modern ears.

Regional and local anesthesia.—Regional and local anesthesia were regarded as of great value in many of the exigencies of war surgery in World War I, especially in rush periods at the front, when it might not be practical to give nitrous oxide-oxygen anesthesia because of the apparatus required, and when prolonged periods of induction and recovery would not be feasible. Even when inhalation anesthesia was available, local anesthesia was regarded as preferable for the excision of damaged soft tissues, the removal of debris, the probing of soft tissues for retained missiles, the amputation of fingers, the repair of scalp wounds, and intracranial operations. The chief disadvantage

³ It should be emphasized again that the data on nitrous oxide anesthesia are presented for their historical interest only. Neither clinical nor experimental evidence warranted the high favor accorded to this form of anesthesia.

⁴ See footnote 1, p. 53.

of local anesthesia was thought to be the possibility that it might decrease the resistance to infection of tissues which were already contaminated.

Pre-anesthetic medication in World War I was limited to morphine.

MILITARY CONSIDERATIONS OF ANESTHESIA

When the United States entered World War II, anesthetists had at their disposal a wide range of agents and techniques. A number of these had been introduced since World War I, including ethylene, ethyl chloride, Pentothal Sodium (thiopental sodium) by the intravenous route, and endotracheal anesthesia. Equipment had been greatly improved. In particular, modern, efficient machines for gas anesthesia had been made possible by the development of the carbon dioxide absorption technique. This technique, although it had been described in 1915, had not come into common use until the decade preceding World War II. It permits measured amounts of anesthetic gases and oxygen to be delivered to the patient, ether being added to the mixture in small quantities until the desired plane of anesthesia is reached. As the gases are expired, they pass through a canister containing a chemical absorbent, by means of which expired carbon dioxide is removed. The gases then pass into a rebreathing bag, and the patient, on inspiration, receives a warm mixture of anesthetic gases and oxygen or of vapor and oxygen.

The closed method of administering gas-oxygen and ether anesthesia has a number of advantages. It greatly reduces the fire hazard, since all gases used are contained in a closed circuit. It also reduces the cost of anesthesia, since the closed circuit conserves whatever agents are used. In addition, this technique permits the maintenance of intermittent positive pressure anesthesia and also permits the anesthetist to control the patient's respiration at will. It is not too much to say that without this, and other, advances in anesthesia, the surgical progress accomplished in World War II would not have been possible.

The wide range of anesthetic agents and techniques available at the outbreak of World War II did not, of course, mean that all of them could be employed according to peacetime practices. In addition to the fact that medicomilitary efficiency could be achieved only by the establishment of standardized methods, there were several other reasons why anesthetic agents, at least in forward zones, were chiefly limited in World War II to ether, Pentothal Sodium, and procaine hydrochloride:

1. The use of cumbersome equipment was undesirable because of the disproportionate amount of scarce shipping space which it occupied in transit to destinations overseas.

2. The use of such equipment was also impractical. Many times during the course of the war, hospital installations in forward areas, even 400-bed evacuation hospitals, had to evacuate their patients; tear down their equipment; move forward, often many miles, often over difficult, congested roads, and sometimes under fire; set up again and be ready to receive patients within 24

hours after the first notification of the move. When such moves had to be accomplished, as well as under other military circumstances, it was almost impossible to protect delicate, complicated apparatus from injury. Gas machines are delicately adjusted, and when they were handled roughly they were likely, in a short time, to leak and to lose their serviceability.

3. The problem of logistics played a further part in the choice of anesthetic agents in forward areas. Interruption of supply channels and constantly changing supply routes soon convinced even anesthetists who had strong preferences for certain agents to the exclusion of others that they must content themselves with fewer agents, preferably those which, when necessary, could be transported by hand and which could be administered, when necessary, by improvised techniques and equipment.

4. The shortages of trained personnel for the administration of anesthetics made it necessary, from the standpoint of safety, to limit the agents employed to those which could be given, without undue risk to the patient, by physicians and nurses of limited experience in this field.

PERSONNEL

The outbreak of World War II found the whole United States with far fewer trained anesthetists than were needed for the practice of the specialty in peacetime. The Army Medical Corps, which represented a cross section of American medical personnel and practice, naturally reflected this shortage. Furthermore, because of the previous Army policy in regard to training medical officers as anesthetists, it was not until March 1939 that a 6-month course of instruction was begun at the Mayo Clinic by the first medical officer to be designated for formal training in anesthesia since World War I. When he completed his course, he was replaced by another officer, and this limited policy was still in effect at the time of Pearl Harbor. While these officers were being trained, nurses continued, as previously, to give inhalation anesthetics in the various Army hospitals in the United States. Spinal, local, and regional anesthetics were given by the surgeon himself or by some other medical officer designated for this purpose.

The Army shortage of trained personnel in anesthesia was seriously reflected in the North African Theater of Operations, where the first prolonged fighting against the western Axis powers took place. Of the 77 physicians in the theater designated as specialists in anesthesia, only 10 percent had been certified by the American Board of Anesthesiology. Fifteen percent of the so-called specialists in anesthesia had been trained in courses which lasted from 1 to 3 months, and 20 percent had had no training at all except what they had obtained incidentally, during surgical residencies and rotating internships.

The small number of physicians available for assignment to anesthesia in the Mediterranean (North African) Theater of Operations was compensated for by a number of substitutions and shortcuts:

1. Although shortages in personnel seldom seriously slowed down the care

of casualties, the possibility was always a constant and uncomfortable threat. When the situations arose, dentists, as had been arranged previously, helped out voluntarily.

2. A good many medical officers who had had little, if any, special preparation in anesthesia were also pressed into service.

3. Aidmen, under close supervision, sometimes gave anesthetics in times of stress in forward areas. This was not a desirable expedient. These men, because of their earnest application to their duties, often rendered good service, but, in general, this was not a satisfactory plan.

4. Continuous training of nurses was practiced. Four general hospitals were employed for this purpose in the Mediterranean theater. They were more suitable for supervised training in anesthesia than were forward hospitals. Theoretically, the course of training was 3 months. Actually, how long the student remained depended upon how long she could be spared from her unit. Often this was only 2 months, and sometimes it was only 1 month.

5. Schools of anesthesia were supplemented by individual training given in the various units in the theater. In a number of instances, the unusual abilities possessed by anesthetists in affiliated units working at the rear were utilized in the training of anesthetists to be sent to forward areas.

Surveys made in certain evacuation, station, and general hospitals in the Mediterranean theater in September 1944 showed that the relationship between personnel administering anesthesia and the surgical load varied widely (table 3). The assignments, for obvious reasons, were made according to the function of the hospital. Evacuation hospitals naturally required the greatest concentration of personnel in the forward areas. Field hospitals, in which newly wounded nontransportable men were cared for, and which had a 100-bed capacity per platoon, were usually staffed by four auxiliary surgical teams. Each of these teams included an anesthetist, who was usually a physician, and the setup was such that two operating tables could be kept in continuous use day and night. Occasionally, when the load was particularly heavy, three or four operating tables could be used at the same time in a single platoon, but this arrangement could not be maintained for very long.

As a working principle, it was found best to assign the ablest anesthetists to the combat zone. Here there were the greatest demands on native intelligence, judgment, resourcefulness, and technical ability. In practice, this principle could not always be applied, because physicians in units associated with affiliated schools and hospitals could not readily be detached from them. It was undoubtedly true that surgery undertaken in station and general hospitals in rear areas required at least as much judgment, skill, and training on the part of the anesthetists as were required in forward areas, but it was equally true that the circumstances under which surgery was done in forward areas put a particularly heavy tax upon these qualities and qualifications.

TABLE 3.—*Provision of anesthetic personnel in sample evacuation, general, and station hospitals in Mediterranean theater (September 1944)*

Hospital	Capacity listed	Occupancy ¹	Daily operations	Anesthetic personnel				Remarks
				Physicians	Nurses	Auxiliary surgical group	Aidman in field	
EVACUATION HOSPITALS								
A	750	800	28 to 100	1	2	-----	4, 3 more on second call.	7 tables day, 4 night.
B	400	600	25 to 120	2	3	3	2-----	6 tables day and night.
C	750	-----	50 to 100	1	4	4	2-----	8 tables day and night. 1 physician and 5 nurse-anesthetists care for 50-case days; 4 auxiliary surgical-group anesthetists assist on 100-case days.
D	400	550	60 to 138	2	4	4	1-----	Auxiliary surgical-group anesthetists assist on 138-case days.
E	400	500	50 to 125	1	4	-----	-----	6 internists and 2 auxiliary surgical-group anesthetists assist on 125-case days.
F	750	400	80 to 120	1	4	-----	-----	6 to 8 tables day and night. 1 dentist and 4 internists assist on 120-case days.
GENERAL HOSPITALS								
G	1,500	900	10	1	2	-----	-----	2 anesthesia utilitymen help with apparatus; they do not give anesthetics.
H	1,500	1,700	50	1	6	-----	-----	1 or 2 internists help, as needed.
I	1,500	-----	25	1	3	-----	-----	
J	1,500	1,000	10	1	2	-----	-----	
K	1,500	950	13	1	3	-----	-----	
STATION HOSPITALS								
L	250	348	3	-----	1	-----	-----	1 physician on part-time anesthesia duty. Surgeons give all spinals.
M	500	250	5	-----	1	-----	-----	Part-time physician-anesthetist also has ward.
N	500	400	4	-----	2	-----	-----	3 surgeons cover anesthesia on part-time basis.
O	500	-----	3	-----	1	-----	-----	
P	500	389	6.5	-----	-----	-----	-----	Medical officers rotate on anesthetic duty.
Q	250	490	15	-----	3	-----	-----	4 surgeons cover anesthesia on part-time basis.
R	500	625	4.5	1	-----	-----	-----	

¹ At time of survey.

EQUIPMENT

The portable Heidbrink and McKesson anesthetic machines issued by the Army were of the standard type used in all civilian hospitals. The Beecher

machine ⁵ was designed especially for military use. As early as 1941, the Subcommittee on Thoracic Surgery of the Committee on Surgery of the National Research Council, with a vivid recollection of the high death rate which followed wounds of the thorax in World War I, had attacked this problem from various aspects, with the idea of developing methods of making early transpleural intervention practical. Patients with wounds of the thorax frequently do not tolerate delay in transportation to distant hospitals. At the same time, successful forward surgery could not usually be done in the absence of positive pressure in the airway. The problem, from the standpoint of anesthesia, was therefore twofold: (1) To devise a simple anesthesia apparatus which would be light, compact, and easily carried by hand; and (2) to construct it in such a manner that positive pressure could be developed with it, without dependence on tanks of oxygen, the provision of which, it was then thought, would be impractical in forward areas of active combat.

The machine designed to meet these requirements (figs. 8, 9, and 10) consisted of the following parts: A foot bellows, with air intake well above the floor; an air reservoir bag; an air-reducing valve and a reducing valve arrangement which permitted the use of compressed oxygen when it was available;

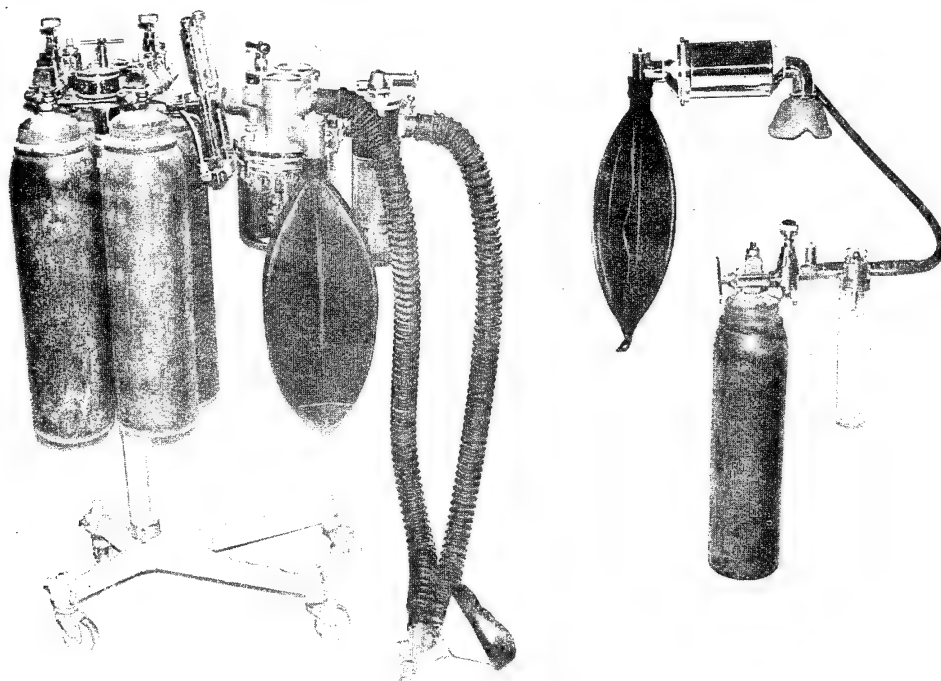


FIGURE 8.—Transportable anesthetic apparatus for administration of ether in simplified closed system with and without oxygen.

⁵ Beecher, H. K.: An Easily Transportable Apparatus for Anesthesia With or Without Compressed Oxygen. Especially Designed for Positive Pressure Anesthesia in Thoracic Surgery Under Military Conditions. War Med. 2: 602-608, July 1942.

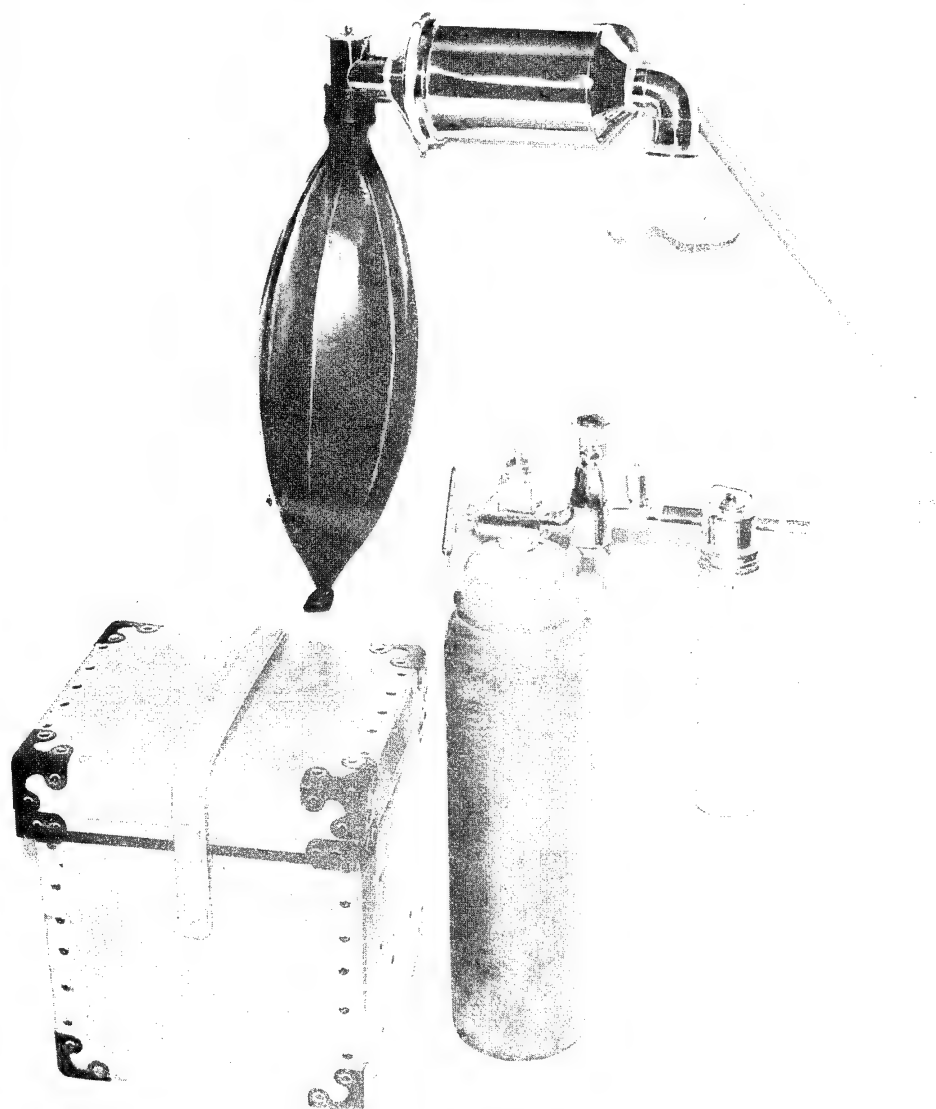


FIGURE 9.—Transportable anesthetic apparatus in carrying case and set up.

a safety blowoff valve; an ether-vaporizing bottle with a string wick, to promote rapid volatilization of ether; a face mask; and a breathing bag with a to-and-fro soda-lime filter (Waters' type for the removal of excreted carbon dioxide). At the distal end of the soda-lime canister was an adjustable vent, which was chiefly used when room air was employed. An intake tube 3 feet long, which could be attached to the operating table, maintained the air intake of the foot bellows at a considerable distance above the floor so that no floor



FIGURE 10.—Administration of ether in simplified closed system in evacuation hospital in Italy, 1944.

dust was taken up. The parts of the machine made of rubber were preferably made of conductive rubber. The machine permitted the maintenance of positive pressure in the airway when this was necessary, but at the same time could be so adjusted as to allow the gradual escape of air from which part of the oxygen had been extracted during respiration.

Several changes were made in the original model after it was tested in actual use. It was found that the foot bellows could be dispensed with because oxygen was available in forward as well as rear areas. It was also found advantageous to add a dropper of the oil-cup type, to enrich the ether atmosphere. Finally, the machine was further simplified by elimination of the flow meter, which was not really necessary for the air or oxygen used in maintenance. If the breathing bag was kept adequately filled and if care was taken to see that the patient's blood was always of good color, nothing else was needed beyond the respiratory excursions adequate to remove carbon dioxide.

This machine was carried, by hand when necessary, in a compact container measuring 10 by 10 by 19 inches (fig. 9). The container was large enough to contain additional supplies, including a laryngoscope (Eversole) with the battery in the handle, and 2 extra light bulbs for it; 2 rubber intratracheal tubes (Magill, #29 and #32); an aspiration bulb and catheter (Flagg) for clearing out the bronchi; a small packet of the agent used for induction, usually Pentothal Sodium; and 2 cans of ether (1 pound each). When the container was fully loaded, the total weight was 25 pounds. The machine itself was so small that it occupied little space in a crowded operating tent, and it was so simple and durable that there were few parts to get out of order and few opportunities for leakage. An additional advantage was that it required only small amounts of critical materials for its manufacture.

Anesthesia could be induced with this apparatus by the so-called straight ether method at least as conveniently as by the open cone method. Civilian experience had shown that induction with nitrous oxide was satisfactory in transpleural surgery, but nitrous oxide was seldom available at the field-hospital level. Pentothal Sodium was sometimes used for induction in ether anesthesia, but this agent was not safe, even for this limited purpose, in seriously wounded men (p. 72).

Although one of the reasons the Beecher machine had been devised was to make thoracic surgery feasible without the use of compressed oxygen, this did not mean, of course, that oxygen was not used when it was available (fig. 11). As a matter of fact, and contrary to expectations before the war, oxygen was supplied at most forward installations. If the amounts available were limited, it could be added in small quantities to the room air in the system during the period the pleura was open. If, for instance, the pleura was open for 30 minutes, the addition of 9.5 liters (2.5 gallons) of compressed oxygen aided greatly in maintaining ideal operating conditions. Compressed oxygen was thus conserved, and a little was made to go as far as possible. When compressed oxygen was not available, a constant flow of room air was maintained through the apparatus. When the system was constantly flushed in this manner, it was not necessary to use the soda-lime carbon dioxide absorbent.

Although the Beecher machine was devised specifically for use in thoracic surgery, experience in the combat zone proved its usefulness for any other type of operation in which inhalation anesthesia was employed. It could also be used for the administration of oxygen and for artificial respiration.



FIGURE 11.—Administration of ether with oxygen in simplified closed system in evacuation hospital in Italy, 1944.

ANESTHETIC AGENTS

The pattern of anesthesia had been clearly established by September 1944 in the North African (Mediterranean) Theater of Operations, where there had been active and often intensive combat since November 1942. Ether had emerged as the agent of choice for operation on seriously wounded soldiers, and its corresponding merits in men who were better risks had also become evident. Local anesthesia had been shown to be inadequate for major procedures and was not well tolerated by apprehensive, badly wounded men, who frequently had multiple wounds and who sometimes were in great pain. Intravenous anesthesia with Pentothal Sodium had its first valid trials in military surgery during the fighting in North Africa. After a proper regimen for its use had been established and limitations and contraindications had been determined, it was found to be admirably suited for the needs of war surgery.

In the following sections, the advantages and disadvantages of the various anesthetics and techniques available at the outbreak of World War II are briefly discussed from the standpoint of their use in combat zones. In station and general hospitals, there were no special problems of anesthesia because conditions in them approximated those in civilian hospitals.

Spinal Anesthesia

When spinal anesthesia was first introduced, its tendency to cause a fall in blood pressure was so significant and so serious that its use was almost discontinued. Then it was found that vasoconstrictor drugs could control this effect, though the most potent vasoconstrictors could not maintain levels of safety in patients who had suffered severe trauma and had lost large amounts of blood.

Spinal anesthesia was additionally undesirable for another reason. When it is used, the vasomotor fibers are the first to be paralyzed and the last to recover. The area over which this effect occurs is larger than the area over which the pain response is eliminated, since to interrupt vasomotor control requires a lower concentration of whatever agent may be employed than is required to interrupt pain sensation. Spinal anesthesia therefore breaks down an important body defense against shock by the interruption of vasomotor control, which is one of its integral effects.

In spite of these well-known disadvantages, many surgeons contended in the first years of the war that spinal anesthesia was desirable in military surgery. Many American surgeons argued for its employment, in spite of the data concerning its risks and inefficiency which came in from areas of combat early in the war, on the ground that errors of administration could account for the unsatisfactory results.

Studies reported from the Massachusetts General Hospital⁶ in 1943

⁶ Beecher, H. K.: The Choice of Anesthesia for Seriously Wounded Patients. J. A. M. A. 121 899-903, 20 Mar. 1943.

effectively answered these arguments. These studies were carried out in two series of patients with perforated peptic ulcers. The patients, chiefly men, of an average age of 44 years, were seen within 30 minutes to 40 hours of the accident, and all were submitted to the same well-standardized reparative operation. One group was operated on under spinal and the other under ether anesthesia. Whether the administration was by widely experienced anesthesiologists or by beginners, a fall in blood pressure was observed twice as frequently when spinal anesthesia was used.

Spinal anesthesia had a limited use early in the fighting in the North African theater, but its popularity decreased as it came to be appreciated that there were few indications for its employment in forward areas. One reason for limiting its use in these areas was the difficulty of preserving sterility of equipment in the field. A more potent argument was the poor tolerance of freshly wounded men for it, as indicated by the tendency of the blood pressure to fall when it was used. The condition of the circulation, always precarious in a freshly wounded man, deteriorated rapidly when it was employed, and eventually few surgeons or anesthesiologists, whatever their practices and preferences might have been in civilian life, recommended its use in forward areas, even in lightly wounded men. It always had, of course, a considerable and proper use in hospitals to the rear.

A survey of 12 hospitals in September 1943 showed that, since November 1942, spinal anesthesia had been used in almost 20 percent of the operations in forward hospitals. A second survey, in August 1944, showed that in the intervening period it had been used in only 3 percent of operations in forward hospitals. Further analysis showed that this proportion was composed largely of emergency appendectomies and other operations not related to warfare. The sharp decrease in its use indicated, as already noted, both a realization of and an acceptance of the fact that spinal anesthesia is usually a poor choice in badly wounded men and may, indeed, be a major error.

Local (Regional) Anesthesia

Local anesthesia must always be considered when a noninflammable anesthetic is required or when surgery must be carried out on traumatized and exsanguinated patients for whom it would be adequate. The English experience early in the war, however, showed that the moderate discomfort and psychologic trauma associated with its use made this type of anesthesia poorly tolerated by seriously wounded men who were aware of their condition and surroundings. In their hands, as later in American hands, it was sometimes useful for minor surgical procedures on phlegmatic or apathetic subjects, but appraisal of the patient's possible tolerance for occasional discomfort and other inconvenience was an essential preliminary to the decision to employ it.

The technique of local anesthesia is not difficult for surgeons who use it regularly and have had special experience with it. In other hands, there is a considerable proportion of partial successes and actual failures. These difficulties made local anesthesia time consuming and furnished another sound

reason for its limited use under combat conditions in the Mediterranean Theater of Operations in World War II. Finally, the soundest reason for the limitation of its use was the multiplicity of wounds usually present in each case. In these circumstances, it was not a practical method.

Harmful circulatory effects can occur from the use of too large amounts of local anesthetic agents or from their too rapid absorption. These undesirable effects can be minimized by two precautions:

1. The addition of epinephrine hydrochloride (1:200,000 in the optimum final dilution). This practice prolongs the anesthetic effect perhaps fivefold and at the same time reduces the quantity of procaine hydrochloride needed. Vaso-constricting agents should not be used, however, in operations about the genitals or on the fingers, toes, ears, or nose, because of the danger of sloughs. They should not be employed when cyclopropane, chloroform, ethyl chloride, or Avertin (tribromoethanol solution) are to be used, because of the danger of ventricular fibrillation. Finally, they should be employed with great care, if at all, in patients with organic circulatory impairment.

2. Careful attention to dosage. Toxicity from the absorption of local anesthetic agents increases in geometric progression as the dosage is increased. Thus it is usually safe to give an able-bodied man 150 cc. of 1-percent procaine solution over a period of an hour but dangerous to give him 75 cc. of 2-percent solution over the same period. Not more than 35 cc. of the 2-percent solution can be used with safety in the space of an hour.

Within the limitations and with the precautions specified, local and regional block, chiefly with procaine hydrochloride, proved useful in certain neurosurgical and maxillofacial operations, as well as in minor surgical procedures. It also had other uses. In the form of intercostal and paravertebral block, procaine hydrochloride was useful in controlling pain in the traumatized chest wall, with consequent improvement of the respiratory function, and in improving the blood supply to an extremity. Peritoneal block under direct vision after the abdomen was opened often improved relaxation of the abdominal wall to such a degree that only light general anesthesia was necessary.

When topical anesthesia was indicated, it was accomplished with Pontocaine (tetracaine hydrochloride) or cocaine.

Chloroform

From the theoretical standpoint, chloroform has a number of advantages. It can be administered smoothly with a minimum of equipment. Its potency is so great that only low concentrations are needed in inspired air, and adequate oxygenation can be obtained from the atmosphere of the operating room. It produces excellent muscular relaxation. It is easily transportable, and it does not burn or explode.

These advantages are outweighed by a number of disadvantages and dangers. The ventricular fibrillation, central hepatic necrosis, and destruction of the convoluted tubules of the kidneys which chloroform is capable of producing can cause death or serious and permanent disability. Its effect on the

circulation is profoundly depressing. It slows the heart rate, weakens the strength of the cardiac contractions, reduces the cardiac output, and depresses the blood pressure. It also causes acidemia. Hepatic damage produced by chloroform can be minimized by its administration with high concentrations of oxygen in inspired air and by a diet high in protein and carbohydrate; but these precautions are not always possible under conditions of combat, and they do not alter the possible effects of chloroform on the circulation.

Chloroform had been practically discredited in civilian practice for many years before World War II, and its effects on the circulation are such that there would seem to be even less reason for using it in men wounded in battle and already suffering from circulatory impairment than in nontraumatic civilian practice. It was therefore almost never used in the Mediterranean theater. With the other agents available, it was difficult to find a legitimate use for it, except when Pentothal Sodium, nitrous oxide, or a local anesthetic agent was not adequate and it was imperative to use a noninflammable agent.

The suggestion was made that chloroform be provided in small ampules for administration by nonmedical personnel to wounded soldiers who had become manic in burning tanks and who might be more easily removed through the narrow escape hatch if they could be controlled. So far as is known, chloroform was not used for this purpose in any theater of operations.

Nitrous Oxide, Ethylene, and Cyclopropane

Nitrous oxide, ethylene, and cyclopropane all have the initial disadvantages, from the military standpoint, that they require steel cylinders for their storage and that they must be used with compressed oxygen.

Nitrous oxide and ethylene have undesirable metabolic effects if they are administered without adequate oxygenation, which is a generally impossible requirement if a full surgical level of anesthesia is necessary. This is particularly true when nitrous oxide is used, since the high partial pressure required leaves little room for oxygen. The same is true, though to a lesser degree, when ethylene is used. Satisfactory muscular relaxation cannot be produced with either of these agents within the limits of safety.

Cyclopropane has deleterious effects on the heart and has apparently caused death from ventricular fibrillation in a considerable number of cases. Aside from this effect, it seems to be better tolerated, from the circulatory standpoint, by animals in shock or in impending shock than any of the other anesthetic agents, with the possible exception of ethylene. Whether this is true of human subjects in shock is not yet known.

Neither cyclopropane nor ethylene was issued to medical officers in the Mediterranean theater. When nitrous oxide was available, it was occasionally used for minor surgical procedures, such as painful changes of dressings. It was also occasionally used to supplement other forms of anesthesia, such as Pentothal Sodium (with 50-percent oxygen), or for induction in ether anesthesia. It was useful for all of these purposes, but it was by no means indis-

pensable. Nor did it rank in efficiency with ether, Pentothal Sodium, or procaine hydrochloride.

Vinyl Ether

Vinyl ether acts rapidly and is readily transportable. In spite of these advantages, it was not used extensively in any theater in World War II because its advantages were outweighed by its disadvantages. It is difficult to use satisfactorily without a closed rebreathing apparatus. It has a tendency to cause laryngeal spasm, profuse salivation, muscular twitchings, and even convulsions and liver damage. It is chemically unstable, and it is possible that the results just listed may be caused by that property.

Ether

Ether is undoubtedly the most useful anesthetic agent for general purposes and under nearly all circumstances, including military circumstances. Its great potency permits an adequate supply of oxygen, even if only room air is available. Its straight induction in seriously wounded men is remarkably easy and is apparently not unpleasant for the patient, whether the open-drop method is used, or, as is preferable, it is given by the closed method, with oxygen (fig. 11). Ether produces excellent muscular relaxation. It is well established that even an impaired circulatory system tolerates prolonged ether anesthesia well. A man in shock, in fact, seems to tolerate ether far better than an animal in shock.

Ether has, on the other hand, some undesirable properties. It is irritating to the mucous membranes of the respiratory tract—though it has never been adequately demonstrated that this characteristic increases the incidence of respiratory complications or the number of deaths from them, while considerable evidence suggests that the irritation which it causes is of no clinical importance. Ether also causes a considerable disturbance of metabolism, the blood sugar frequently being elevated from 100 to 200 percent.

In World War II, ether was the anesthetic of choice in the seriously wounded, whether the gravity of their injuries depended upon widespread tissue destruction, penetration of body cavities, or severe hemorrhage from wounds which in themselves might not otherwise have been of great consequence. Since it was the anesthetic best tolerated by men in shock, it seemed reasonable to use it also in men who were less badly off. In the first months of fighting in North Africa, it was not used as widely as it should have been, at least in forward hospitals. The increase in its use in the second year of fighting may be unimportant statistically, but clinically it is of great significance, since it occurred chiefly in the field hospitals, where the surgically important group of patients was treated. These were the men with wounds of the abdomen and thorax and compound fractures of the femur.

An intelligent appraisal of anesthesia practices is not possible without some knowledge of the type of surgery performed. The mere tabulation of data (table 4) does not tell the full story. The true picture is better obtained from an

analysis of the experience of auxiliary surgical groups, which had a wide experience in forward surgery, particularly in the surgery of nontransportable patients in field hospitals. In such an analysis, surgery of the abdomen and chest assumes greater importance than the tabulated data indicate. Of 15,925 wounded men treated by the 2d Auxiliary Surgical Group, for instance, during the North African, Sicilian, and part of the Italian fighting, 1,628 (10.2 percent) had abdominal injuries, 1,502 (9.4 percent) had thoracic injuries with pleural involvement, and 508 (3.2 percent) had thoracoabdominal injuries. Since the 1,628 abdominal injuries included a number of cases in which exploration was negative, the thoracic injuries may be said to have been approximately as frequent as abdominal injuries in the experience of this group, while the combined total of thoracic and thoracoabdominal injuries exceeded the number of abdominal injuries. The responsibility of the anesthetist in surgery of such magnitude is too evident to need elaboration.

TABLE 4.—*Sample distribution of surgical procedures in the Mediterranean (North African) campaigns (1943-44)*

Area	Number of operations	Site of major surgery						
		Extremities	Abdomen	Chest	Central nervous system	Ear, nose, throat	Miscellaneous	
							Major	Minor
		Percent	Percent	Percent	Percent	Percent	Percent	Percent
Forward (field and evacuation) hospitals.....	9, 199	28. 0	7. 0	3. 1	1. 7	0. 6	3. 3	56. 3
Rear (station and general) hospitals.....	11, 261	13. 4	6. 5	. 8	1. 4	2. 1	4. 5	71. 3

The Barbiturates

Civilian experience up to World War II showed that when the barbiturates (Evipal Sodium (hexobarbital soluble) and Pentothal Sodium) were used for major as well as minor surgery, the death rate, depending upon the quality of the clinic, was likely to be from 3 to 10 times higher than for ether anesthesia. At the Massachusetts General Hospital, where these agents are chiefly used for procedures on able-bodied adults which last less than an hour, 8,000 consecutive anesthetics were administered with barbiturates with no deaths.⁷ Early in the series, however, a number of lessons were learned: That bad-risk patients tolerate these drugs poorly, except when they are used in small amounts as supplements to other forms of anesthesia; that, even in these circumstances, a fall in blood pressure may occur during spinal anesthesia; and that patients with circulatory impairment tolerate full barbiturate anesthesia particularly poorly.

⁷ See footnote 6, p. 65.

Adequate studies have shown that intravenous anesthesia with barbiturates is associated with two other outstanding hazards:

1. It causes a progressive loss, which finally becomes complete, of the sensitivity of the respiratory center to its normal chief stimulus, carbon dioxide, the content of which in the blood may rise to depressant levels during anesthesia with barbiturates.

2. When the normal respiratory drive becomes impaired or disappears completely, a supplementary mechanism is necessary to keep it going. A shift is therefore made from the normal driving action of carbon dioxide on the respiratory center to the action of anoxia on the chemoreceptors, chiefly the aortic and carotid bodies.

Pentothal Sodium was provided in the North African Theater of Operations from the time of the first landings in November 1942. Its ready availability; the simplicity and compactness of the equipment for its administration; the ease and smoothness of induction, even by inexperienced physicians; and the apparent infrequency of undesirable after effects—all made it a popular anesthetic drug under combat conditions. These advantages tended to outweigh other important considerations: That Pentothal Sodium is a powerful tool, that overdosage is not easy to overcome, that the lethal dose varies within a wide range from one patient to another, and that this form of anesthesia is definitely contraindicated in certain types of injury and under certain circumstances.

The results of the casual acceptance of the advantages of Pentothal Sodium without regard for its dangers and disadvantages, were apparent in the first survey of anesthesia made in the theater, in September 1943. Sample data secured from 12 hospitals showed that this agent had been used in 2,672 operations and that in 6 of the fatalities which followed (1:450), death could be attributed only to anesthetic causes. Further investigation at other hospitals produced similar data. Results throughout the theater, in fact, were so bad that it was seriously proposed that this form of anesthesia be abandoned entirely, particularly since the experience in North Africa paralleled the experience reported from Pearl Harbor.

A detailed analysis of the fatalities caused by Pentothal Sodium anesthesia in 1942-43 cast a somewhat more hopeful light upon the situation. Two errors were outstanding, but both were readily correctible. The first was the use of this method of anesthesia by completely inexperienced medical officers, many of whom seemed to have the impression that all that was necessary was for the drug to be injected into a vein. The second error was the frequent use of this method in conditions in which it was actually contraindicated and in which it should never have been employed. The impression derived from the analysis was that if these errors could be corrected and the conditions of its administration controlled, Pentothal Sodium might prove to be, in practice, the ideal anesthetic for certain types of injuries of warfare, just as it had always been in theory.

The decision to continue the use of Pentothal Sodium as an anesthetic

agent in the Mediterranean theater proved sound. A survey conducted in 10 hospitals in the theater in September 1944, a year after the first survey, showed that only 2 deaths could be attributed to its effects in 11,136 operations (1:5,550). In other words, during the period covered by the second survey, Pentothal Sodium, although it had been used in about 4 times as many cases as during the first period, was responsible for only a third as many deaths. The figures indicate the magnitude of the improvement which had been achieved in the course of the year.

It should be emphasized again that this improvement occurred over a period in which the use of Pentothal Sodium had increased considerably. In September 1943, this agent had been used in over 2,500 (53 percent) of the operations performed in the forward hospitals surveyed and in 1,462 (28 percent) of the operations performed in the station and general hospitals surveyed. In September 1944, these proportions had risen, respectively, to 63 percent (6,721 operations) and 48 percent (4,415 operations). A large part of the increase could be explained by the widespread adoption of the practice of secondary wound suture, a procedure for which this type of anesthesia approaches the ideal.

By this time, the indications and contraindications for Pentothal Sodium anesthesia had been standardized. It was regarded as the optimum anesthesia not only for delayed primary wound closure but also for any other procedure which could be performed within 30 to 45 minutes. If the duration of the operation was unexpectedly increased, it was the practice to shift to ether. Pentothal Sodium had a wide use in evacuation hospitals but was seldom used in field hospitals, in which ether was the anesthetic of choice. Long experience in the Mediterranean theater led to the almost universal view that Pentothal anesthesia should never be used in the seriously wounded patient, whether he was in good general condition or not. In the early days, many fatalities apparently due to Pentothal anesthesia occurred, and this contraindication became clear. It was useful for the induction of ether anesthesia in men in good condition but was contraindicated for this purpose in poor-risk patients. It was also contraindicated in the following circumstances unless there was some overriding reason for its use:

1. When shock was present or impending.
2. When the intake or distribution of oxygen was impaired or in any way jeopardized.
3. When an overdose of morphine had been given (p. 41).
4. When severe hemorrhage had occurred, or when the patient had sustained penetrating wounds of the thorax or abdomen or a compound fracture of the femur. Ether was the anesthetic of choice for all such cases.
5. When inflammation was present in the region of the carotid body and carotid sinus. Inflammation in this area apparently causes sensitization of the reflexes in it, and this phenomenon may explain the sudden deaths which sometimes occur under Pentothal Sodium anesthesia in wounds of the neck. Pentothal Sodium and other barbiturates are not highly effective in depressing these

reflexes, and it was best to avoid possible trouble by resorting to another anesthetic. On the other hand, when compound fractures of the face made the administration of an inhalation anesthetic impractical, Pentothal Sodium, in spite of its risks, might be the best choice for incision of a cervical abscess or some similar lesion. When it was employed in such cases, a number of precautions were taken: The patient was heavily atropinized before operation. If the carotid sinus was found to be irritable, the operation was not begun until at least 10 minutes had elapsed since the administration of Pentothal Sodium. Pressure on the carotids was carefully avoided, and, whenever it was feasible, they were blocked with a local anesthetic.

6. When gas gangrene was present. The contraindication to Pentothal Sodium in this condition was based on the fact that the toxins elaborated produce such severe circulatory damage that the patient is, for all practical purposes, in shock. It is true that the skin temperature of the extremities rises under Pentothal Sodium anesthesia, but the elevation does not necessarily imply a better cellular oxygen supply. The elevation may be attributable to the effect of the anesthetic on the arteriovenous anastomoses. Investigations have shown that the lymph flow is greatly reduced by barbiturate anesthesia, in comparison with local or ether anesthesia, and this observation might be construed as evidence that the oxygen supply of the tissues is impaired by it. Such an effect should be avoided in clostridial myositis, in which oxygenation is already deficient.

7. When the operative position or procedure seemed likely to interfere with the airway or make artificial respiration difficult. If, for any reason, Pentothal Sodium had to be used in these circumstances, all the precautions surrounding its use were sedulously observed. This form of anesthesia was avoided, if it was at all possible, in operations which had to be carried out in the face-down position and in operations for maxillofacial injuries involving the airway. If local anesthesia was inadequate, as it frequently was, these patients were best managed by ether anesthesia with endotracheal intubation.

8. When intracranial procedures were necessary. A skillful—or fortunate—anesthetist might sometimes employ Pentothal Sodium anesthesia without an accident, but, for a number of reasons, the risk was not regarded as justified. Intracranial operations were usually of long duration. In a series of 20 typical craniotomies performed in a combat zone in Italy, the average operating time was 109 ± 11 minutes, exclusive of the time for induction of anesthesia. Another reason for avoiding Pentothal Sodium anesthesia in intracranial surgery was the heavy blood loss, which was often a liter or more by actual measurement. The respiratory depression and anoxia which may occur unexpectedly with this form of anesthesia introduced an entirely unjustifiable risk. Anoxia produces immediate swelling of the brain, which can make an intracranial procedure difficult or impossible. Finally, the hic-coughing, laryngeal spasm, and straining occasionally encountered during this form of anesthesia, or during recovery from it, were, as always, highly undesir-

able in intracranial surgery. In most cases, therefore, Pentothal Sodium was avoided, and inhalation anesthesia with ether or local anesthesia with procaine hydrochloride was employed.

9. When severe burns had been sustained. Burned patients, for reasons which were never clarified, were found to tolerate Pentothal Sodium anesthesia poorly. Perhaps the explanation was the great reduction of the circulating blood volume which is characteristic of burns. Whatever the reason, the circulatory impairment from this cause is comparable to the effects of hemorrhage, in which Pentothal Sodium is always contraindicated.

Technique.—When the use of Pentothal Sodium had become standardized in the Mediterranean theater, it was employed according to the following technique:

1. It was used in 2.5-percent solution.
2. Atropine was used routinely for preliminary medication to minimize vagal reflexes. The dose (0.6 mg., gr. $\frac{1}{100}$) was preferably administered subcutaneously about an hour before induction. A second injection of half the original amount was given intravenously just before the anesthetic was started. When the flow of casualties was heavy, this routine was not always practical, and the total dosage (0.6 mg., gr. $\frac{1}{100}$) was given intravenously about 10 minutes before operation. When laryngeal spasm occurred during anesthesia, atropine was again given intravenously, in the same dosage, and without delay, no matter how shortly after the previous injection the emergency occurred.
3. While there was general agreement concerning the usefulness of atropine as a preoperative drug in Pentothal Sodium anesthesia, there was considerably less agreement in principle or practice about the preoperative use of morphine. For one thing, as pointed out elsewhere (p. 42), the reduction in the total quantity of Pentothal Sodium accomplished by the use of morphine had to be weighed against the possible dangers of overmorphinism in the injured man. For another, it was not altogether clear whether morphine heightened the activity of the laryngeal reflex, which was occasionally troublesome in Pentothal anesthesia. Nor was it altogether clear what part was played by morphine in the long depressions which sometimes followed the use of Pentothal Sodium. For these reasons, the administration of morphine was strictly individualized, and it was given before operation or withheld according to the needs of the special patient.
4. The injection was made by an anesthetist or a physician who had been trained in the technique (fig. 12). The patient was under constant observation, and the pulse rate, respiration, and blood pressure were recorded at frequent intervals. It was the neglect of such precautions, which are traditional with other agents, that accounted for the poor record of Pentothal Sodium when it was first used in the Mediterranean theater.
5. As a safety precaution, and always in long operations, oxygen was administered with Pentothal Sodium (fig. 13).



FIGURE 12.—Administration of Pentothal Sodium anesthesia by nurse in evacuation hospital in Italy, 1944.

PRE-ANESTHETIC MEDICATION

Early in the North African fighting, it was found that men who had been seriously wounded in battle needed little pre-anesthetic medication and were better off without it (p. 43). This early experience was repeated, often under extremely adverse circumstances, at Cassino, on the Anzio beachhead, in the Po Valley, and all through the campaigns in northern Italy and southern France.

Atropine before ether anesthesia was usually given to cut down the flow of mucus and minimize the vagal reflexes. The latter objective was particularly important in certain types of operations, including operations on the thorax; within the abdomen, especially the upper abdomen; and on the neck when inflammation was present in the region of the carotids (p. 72). The dose (0.6 mg., gr. $\frac{1}{100}$) could be repeated within an hour if necessary. Atropine was also useful, as already mentioned, when intravenous anesthesia with Pentothal Sodium was employed, to counteract the laryngeal spasm which occasion-

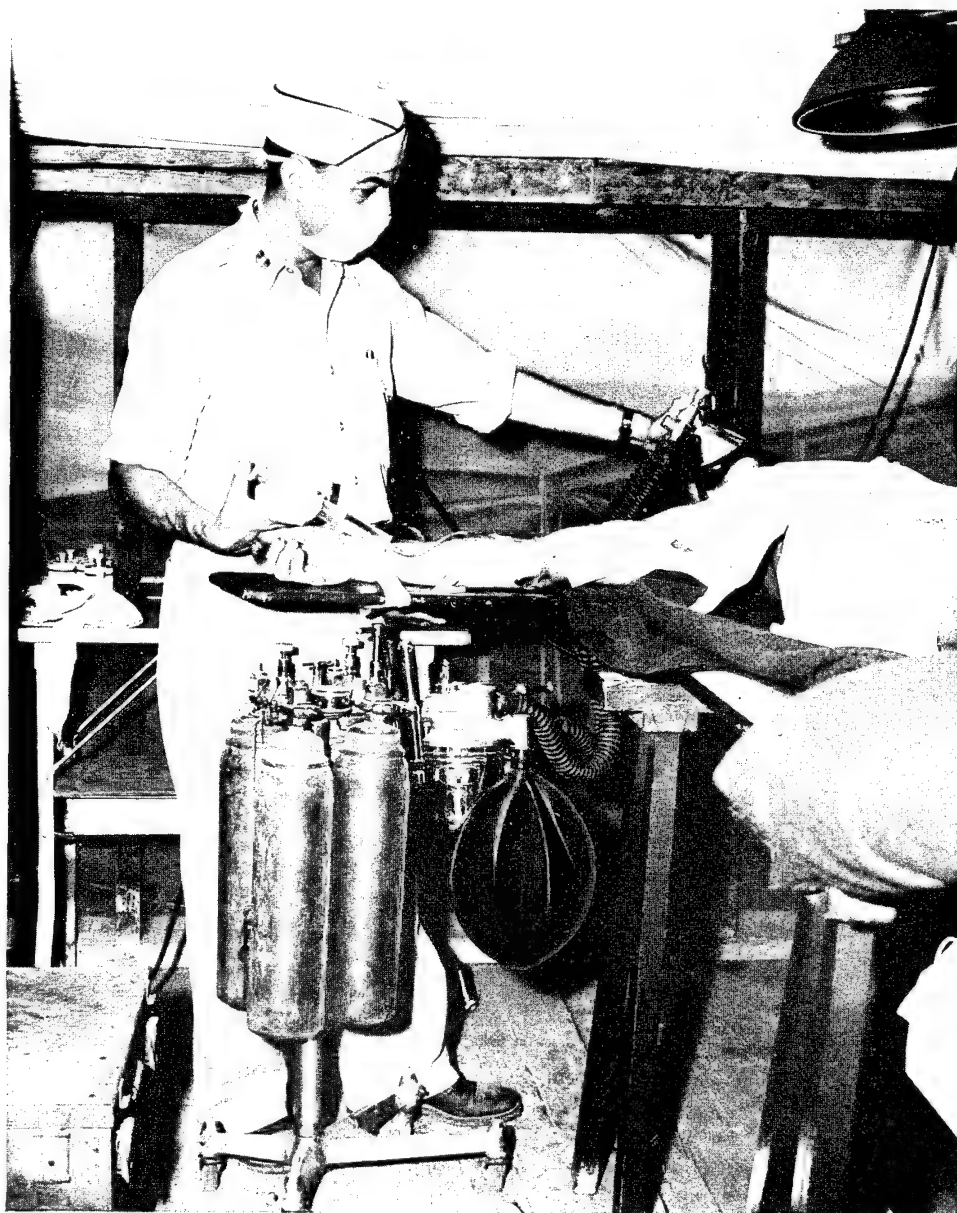


FIGURE 13.—Administration of Pentothal Sodium anesthesia with oxygen by medical officer in evacuation hospital in Italy, 1944.

ally occurred when this agent was used (p. 74). When spasm became troublesome, a second injection was usually employed and was given intravenously.

Morphine was given with great caution or was withheld entirely. As pointed out elsewhere (p. 42), the peripheral circulation was always poor in

chilled and shocked wounded men, and the morphine usually given as a first-aid measure might not have been absorbed from the subcutaneous deposit. When resuscitation had been effected, and later when vasodilatation occurred in response to ether anesthesia, poisoning was always a possibility if the injection of morphine was repeated and the double dosage was taken up into the blood.

Morphine was given when local anesthesia was employed if pain or considerable discomfort was present or seemed likely to ensue. In addition, Pentothal Sodium was given by mouth in divided doses of 90 to 180 mg. (gr. $1\frac{1}{2}$ to 3) about 45 minutes before operation. Morphine was also used when it was thought that pain was severe enough to interfere with the induction of anesthesia. It was given intravenously 5 or 10 minutes before operation, always in small doses. This method of administration was routine during periods of heavy action.

ENDOTRACHEAL INTUBATION AND BRONCHOSCOPY

Endotracheal intubation was employed routinely in all intracranial, maxillofacial, and abdominal operations performed under general anesthesia. It was also used routinely in all thoracic operations in which the pleura was involved. Finally, it was employed routinely in any operation likely to exceed an hour in duration. Otherwise, it was used, as a general rule, only when the operative position was such that maintenance of a satisfactory airway was difficult. Endotracheal intubation had a far wider application on the level of the field hospital than on the level of other hospitals.

The preparation of seriously wounded patients for surgery always included a check on the availability of a bronchoscope, but the instrument was not employed routinely, even in open thoracic operations. If the airway could be kept clear by frequent aspiration through a catheter in the trachea, the simpler procedure was preferable, and bronchoscopy was resorted to only when this could not be done.

Some surgeons and anesthetists advocated the routine use of the bronchoscope at the end of all major operations. This practice was considered undesirable by the majority of medical officers in both groups for two reasons:

1. If the bronchoscope was introduced at this time, it was necessary either to maintain general anesthesia at a deep level for a longer time than was otherwise required, or the anesthesia had to be deepened for this purpose. Neither practice was desirable at the end of a trying operation, when the patient's condition might be poor.

2. If ether anesthesia was not maintained or deepened, topical anesthesia had to be employed for bronchoscopy. Under these circumstances, if the patient vomited during his reaction from general anesthesia, it was almost impossible to prevent the aspiration of vomitus through the locally anesthetized airway.

ANESTHETIC DEATHS

There is not always full agreement in civilian practice on what constitutes an anesthetic death. In the Army, the decision could be more arbitrary. It was the usual practice to classify in this category any death which occurred without adequate explanation in the condition of the patient or in the operation performed and which followed a pattern characteristic of death under the particular agent employed.

The two surveys of anesthesia made in the Mediterranean Theater of Operations in September 1943 and September 1944 showed a total of 12 deaths attributable to anesthesia in 27,564 administrations of anesthetic agents. There was a considerable difference in the distribution of the fatal cases. There were 8 deaths in the anesthetics reported from the hospitals included in the 1943 survey, roughly 1:1,000, against 4 deaths in the 19,914 anesthetics reported from 10 hospitals in the 1944 survey, roughly 1:5,000. Clearly, as methods became standardized and experience increased, anesthesia became increasingly safer for the seriously wounded man.

Part II

ABDOMINAL INJURIES AND THE
INITIAL SURGERY OF
ABDOMINAL WOUNDS

W. Philip Giddings, M. D., Editor

CHAPTER IV

Derivation of Data, Source Material, and Methods of Analysis

W. Philip Giddings, M. D.

The data presented in the following pages, which concern only forward surgery of abdominal injuries, are derived from the report to The Surgeon General, United States Army, dated 27 August 1945, which describes the activities of the 2d Auxiliary Surgical Group in the Mediterranean (North African) Theater of Operations and in the European Theater of Operations during World War II.¹ In numerous instances, these data are characterized by the omissions and discrepancies inevitably associated with the collection of medical data under combat conditions. It is therefore important that the manner in which they were collected and compiled should be clearly understood.

THE 2D AUXILIARY SURGICAL GROUP

The 2d Auxiliary Surgical Group functioned under Table of Organization 8-571, which authorized 121 medical officers, 11 dental officers, 70 members of the Army Nurse Corps, and 176 enlisted men. The enlisted men were, for the most part, surgical technicians who had been graduated from training schools operated by the Army Medical Department. The personnel of the group was broken down into surgical teams, 28 of which were assigned to general surgery and the remainder to the various surgical specialties. As a rule, each team consisted of 6 members; namely, a surgeon, an assistant surgeon, an anesthetist, an operating-room nurse, and 2 enlisted technicians.

Except for a small permanent headquarters, the group maintained no formal installation of its own. Instead, the surgical teams functioned on detached service with various other organizations. After the Sicilian campaign, in 1943, the 2d was the only auxiliary surgical group assigned in the North African Theater of Operations. During 1944 and 1945, its surgical teams were employed by the Theater Chief Surgeon chiefly to furnish surgical care in field hospitals and to augment the staffs of evacuation hospitals as special needs arose. Individual teams were sometimes attached to British mobile casualty clearing stations, installations which in setup and function resembled United States Army field hospitals.

Teams from the 2d Auxiliary Surgical Group also participated in all major amphibious operations of the Mediterranean campaigns, including the initial landings at Anzio-Nettuno and in southern France. On these missions, they

¹ Forward Surgery of the Severely Wounded. A History of the 2d Auxiliary Surgical Group, 1942-45, vols. I and II.

functioned with field and evacuation hospitals, division clearing companies, and, during early phases of the operations, with special troops (Rangers). In August 1944, about half of the personnel of the group was attached to the Seventh United States Army for the invasion of southern France. These teams remained with the Seventh Army until the end of the war, passing with it across France and Germany and into Austria. On this mission, they were divorced from the remainder of the group for almost a year.

Most of the work reported in the following chapters was done in the platoons of the field hospitals customarily situated in close proximity to division clearing stations during periods of combat. These hospitals, which were small, mobile surgical units, were placed well forward, and their staffs were augmented with competent surgical teams on detached service from the auxiliary surgical group. Nontransportable casualties, after being selected by triage in the nearby clearing stations, were sent directly to these hospitals for resuscitation and urgent surgery. All patients with abdominal injuries were classified as nontransportable.

Some installation such as the field hospital was essential for the prompt treatment of abdominal wounds. It was also essential for psychologic and humanitarian reasons. The morale of combat troops was strikingly improved by the knowledge that if they were wounded, all facilities for their care were ready at hand and that, as far as possible, their priority for treatment would be proportionate to the severity of their injuries. The morale-raising effect of this knowledge was repeatedly commented upon both by combat officers and by enlisted men, even those who had not become casualties.

Field hospital platoons, because of their geographic position within the division area, were often uncomfortably close to legitimate military targets. They almost always worked forward of Allied heavy artillery and always worked within range of enemy artillery. At the Anzio beachhead, they were many times subject to shellfire and to aerial-bombing attacks. Frequent changes of location were necessary for tactical reasons, and, on occasion, undesirably early evacuation of patients was necessary to protect them from enemy action. These facts go far to explain deficiencies and discrepancies in the data to be presented.

SOURCE MATERIAL

The source material of this report is 3,154 patients with abdominal injuries treated by the surgeons of the 2d Auxiliary Surgical Group in forward surgical installations during 1944 and until the conclusion of the fighting in Italy and elsewhere on the European Continent in May 1945.² This material does not include (1) casualties operated on by surgeons on temporary duty with the group nor (2) 371 casualties with abdominal injuries treated in 1943, during the Tunisian and Sicilian campaigns and during the first 4 months of the fighting

² Unless specifically noted to the contrary, the terms "patient," "casualty," "case," "wound," and "injury" refer to single cases or patients. Multiple injuries were numerous in this series of cases, but the analysis is always made on the basis of single cases or patients unless otherwise specified.

in Italy. These cases are the subject of previous reports³ and are mentioned in these chapters only occasionally, for comparative purposes.

All 3,154 abdominal injuries were the result of the violence of warfare, 3,052 being caused by combat missiles. Approximately 90 percent of the casualties sustained their injuries in actual combat. Wounded civilians, soldiers of other Allied armies, and prisoners of war made up about 15 percent of the series.

The series includes, in addition to injuries of intraperitoneal organs and of extraperitoneal abdominal viscera, 839 thoracoabdominal wounds, 26 injuries of intraperitoneal viscera in which the abdominal wall was not penetrated (pp. 329, 331), and 333 injuries in which exploration of the peritoneal cavity revealed no intraperitoneal injury (p. 95).

METHODS OF ANALYSIS

This analysis was planned late in 1943, and the compilation of data was begun 1 January 1944. Mimeographed forms (fig. 14), prepared with special attention to brevity and completeness and entirely separate from standard army forms (field medical record), were supplied to the various surgical teams, with instructions to keep a separate clinical record for each patient treated. The accumulated completed case histories were sent periodically to the 2d Auxiliary Surgical Group Headquarters, where they were indexed and filed.

Compilation of data for the final report was begun in December 1944, but for obvious reasons not a great deal could be done until after the German surrender, in May of the following year. Intensive work was started in June 1945, when most of the teams were recalled from the field, the teams detached to the Seventh United States Army returned, and the entire group was reunited at Riva, Italy. For the next few months, all personnel who could be spared from other duties cooperated in the preparation of the report to The Surgeon General,⁴ of which the section on abdominal injuries represents about a third. The entire report required the review of, and tabulation of data from, approximately 22,000 case histories.

The various sections of the report were prepared by individual medical officers, who worked under the direction of an editorial board composed of six officers. Nurses and enlisted personnel assisted in clerical capacities, and the final report prepared overseas represented the combined efforts of at least 200 persons. The last work on it was done during the period of redeployment, when clerks and typists, as well as medical personnel, were constantly being transferred out of the unit. Upon the termination of the operational activities of the 2d Auxiliary Surgical Group in the summer of 1945, a small number of officers and enlisted men, who had formally expressed the desire to remain in Riva until the report was finished, completed the work in August 1945.

³ Report on the Surgery of Abdominal Wounds (unpublished data), submitted to the commanding officer, 2d Auxiliary Surgical Group, 14 April 1944.

⁴ See footnote 1, p. 81.

FIGURE 14.—Summary sheet used by surgeons of the 2d Auxiliary Surgical Group for collection of data on abdominal injuries. Details of operation and the progress notes were entered on reverse of sheet. The abbreviation "Sulpha po loc." refers to the post-operative local use of sulfonamides.

In its present form, the material on abdominal injuries represents a complete revision made in the United States. The original worksheets were reviewed, all the data were subjected to recount and careful review, and revised data were thus secured for a number of sections, including those on timelag and the multiplicity factor. The entire manuscript was then rewritten, many sections

several times, to incorporate these revisions and to give the authors the opportunity to introduce whatever second thoughts had occurred to them in a more normal environment than that in which the original manuscripts were prepared.

LIMITATIONS OF THE ANALYSIS

The source material used in this report was naturally affected in respect to both completeness and accuracy by certain uncontrollable military circumstances. In an occasional case, the special record form had not been filled out and had to be discarded. Some records were lost or destroyed, as the result of enemy action or for other reasons. Information secured from the patient himself, or even from his emergency medical tag, was sometimes open to question. There was often doubt as to the precise hour of wounding; whether the sulfonamide pills in the medical kit had been taken as soon as the wound was sustained, if at all; how much morphine had been given, and when it was given; and how much plasma had been given prior to the patient's admission to the field hospital. These and other details were sometimes recorded incompletely on the battlefield and in transit, or, occasionally, were not recorded at all, and the patients themselves could recall them only hazily. In the field hospitals, forced evacuation of casualties and the frequent shifting of surgical teams militated against the maintenance of complete case histories. Finally, during times of stress, when the load of casualties was heavy and continuous, recorded data had to be limited to little more than brief statements concerning the nature of the wounds and the surgical procedures.

Most patients with abdominal wounds stayed in forward hospitals only briefly. Although the range of forward hospitalization per patient in days was from 1 to 30, the usual period of hospitalization was from 8 to 14 days. This fact, combined with the unavoidable deficiencies of records kept under field conditions, explains the statistical inadequacy of the section on post-operative complications (p. 203). Progress notes were, understandably, often sacrificed to the press of other duties or to the imperative need of overworked surgeons for some rest.

One point which should be emphasized at this time and which will be discussed again later (p. 94) is that the 756 deaths known to have occurred in these 3,154 abdominal injuries are only the fatalities recorded in the forward hospitals in which the initial surgery in these cases was performed. The other (presumed) fatalities were lost to the records for a variety of reasons. Some patients were evacuated as a consequence of enemy action. When, for example, a field hospital was shelled out of action on the Anzio beachhead, some patients who had only recently been operated on were moved to other hospitals, and, in spite of efforts to trace them, their ultimate fate was not discovered. Some of them very probably died. In other instances, the followup records were

incomplete, usually because the surgical teams were moved and the patients were left in other hands early in their postoperative course. Some of these patients unquestionably died. Finally, what happened to most of the patients after they left the field hospitals in which they were operated on also is not known by the writers of this report, though there is no doubt that the great majority of all fatalities from abdominal wounds occurred in these forward hospitals.

In addition to the errors and discrepancies inherent in the collection of medical data under combat conditions, one other possible source of statistical error must be mentioned, namely, the intrinsic human error which invariably and inevitably enters when a large number of different persons interpret the same data. This error was enhanced by the fact that because of the special circumstances in which this report was compiled, a consistent editorial policy could not be developed in advance of the analysis of the data. The policy, in fact, evolved with the project. Since all questions which might involve conflicts of views between individual authors could not be foreseen, data derived by different authors from the same source material were not always presented in the same manner. There was, for instance, no predetermined policy about whether or not to classify nonperforating trauma to the walls of hollow viscera under visceral injuries. Some authors therefore included it in these injuries, while others excluded it. In the section on injuries to the jejunum-ileum, this type of injury is included as a visceral wound. In the chapter on wounds of the colon, it is not thus included. In certain other chapters, it is not always clear which of these policies has been followed. Again, the authors of the section on wounds of the colon, when they encountered the case history of a single perforation of the colon and a severe contusion of the ileum, listed the case as an instance of a univisceral wound of the colon. The authors of the section on wounds of the jejunum-ileum classified the same case as a multivisceral wound of the ileum complicated by a wound of the colon (p. 241). Variations in critical standards thus led to certain numerical discrepancies which could not be reconciled after the original work had been completed and the group had separated.

The statistical material in this report cannot now be supplemented or altered, and such errors as it contains must stand. Nevertheless, when the report was completed, it was the unanimous opinion of the surgeons of the 2d Auxiliary Surgical Group that the presentation was substantially correct. For one thing, the series is of such magnitude that, in the main, positive and negative errors probably have canceled each other out. For another, the conclusions to which the data point represent the consensus of the surgeons of the group, partly as determined by informal polls and partly as derived from the uniformity of practice reflected in the case records. Finally, there was general agreement that the trends reflected by the statistical data are entirely consistent with wartime clinical experiences.

THE CONCEPT OF ABDOMINAL SURGERY IN WORLD WAR II

The concept of management of abdominal wounds underwent a radical reversal in the years before World War II.⁵ Between the Boer War (the South African War of 1899-1902) and the outbreak of World War I in 1914, the policy was one of strict nonintervention. The wisdom of this policy began to be questioned by many surgeons as World War I progressed, and by the end of hostilities there was rather general agreement that most abdominal injuries should be treated surgically, though lack of organization had prevented as wide an implementation of this principle as was desired. During the Spanish Civil War (1936-39), when competent surgeons were available and facilities and organization were adequate, prompt intervention was the rule,⁶ and the number of cases in which the wounds were regarded as too severe to permit surgery were relatively few.

The fundamental objective in the management of abdominal injuries in World War II was as prompt surgical intervention as possible in all casualties to whom the mere act of operation would not be fatal. Surgery was almost never withheld on the grounds of the severity of the wounds; the precise figures are not available, but it is certain that considerably less than 1 percent of the casualties with abdominal injuries who came under the care of surgeons of the 2d Auxiliary Surgical Group were regarded as too severely wounded to withstand operation. No matter what the man's condition might be when he was first seen, vigorous resuscitative measures were at once instituted, in the expectation that surgery would be done. A small proportion of these casualties failed to respond and died during the attempt at resuscitation, but they were the exceptions. In all other cases, the goal of giving every man with an abdominal wound the benefit of surgery could be met.

DEFINITION OF TERMS

In the past, the terms "uncomplicated" and "complicated" have frequently given rise to misunderstanding and confusion when they were applied to wounds. In this analysis, they have been replaced by the terms "univisceral" and "multivisceral," which are used in the following special senses:

1. The term "univisceral" refers to an abdominal wound in which a single viscus has been injured. It carries no implications concerning the number of injuries any single organ has sustained. Simultaneous perforations of the cecum and sigmoid colon, for instance, are classified as a univisceral wound of the colon.

2. The term "multivisceral" refers to a wound in which more than one viscus has been injured, again without any implications concerning the number

⁵ Bailey, Hamilton: *Surgery of Modern Warfare*. Baltimore: the Williams and Wilkins Co., 1944, vol. II, pp. 867-869.

⁶ Jolly, Douglas W.: *Field Surgery in Total War*. New York: Paul B. Hoeber, Inc., 1941, p. 166.

of injuries each single organ has sustained. Coincidental injury to the colon and the ileum, for instance, is regarded as a multivisceral wound of either the colon or the ileum.

3. The term "associated wound" refers to a wound of a part of the body other than the abdomen.

CHAPTER V

Distribution of Injuries and Other Statistical Data

*Luther H. Wolff, M. D., Samuel B. Childs, M. D., and W. Philip
Giddings, M. D.*

DISTRIBUTION OF INJURIES

The statistical material used in this study is heavily weighted by a preponderance of first-priority casualties. About 90 percent of the 3,154 casualties were operated on in field hospital platoons (table 5), and most of the remainder (7.4 percent) were operated on in evacuation hospitals. The case fatality rate for each type of installation clearly reflects the severity of the injuries treated in it.

TABLE 5.—*Distribution of injuries and deaths in 3,154 abdominal injuries, by hospital installation*

Type of installation	Number of cases	Percent of total	Deaths	Case fatality rate
Field hospital.....	2,851	90.4	693	24.3
Evacuation hospital.....	232	7.4	35	15.1
Casualty clearing station (British).....	58	1.8	26	44.8
Clearing station.....	10	.3	1	10.0
Not stated.....	3	.1	1	33.3
Total.....	3,154	100.0	756	24.0

As might be expected, the actual numbers of abdominal wounds observed in the various campaigns varied directly with the fury of the fighting, each offensive and each lull being mirrored in the number of casualties treated (fig. 15). The exact relationship of abdominal to other injuries is not known, but it is reasonable to assume that the curve for them closely paralleled the curve for all casualties.

Since the infantry, as always, bore the brunt of the fighting, it naturally received the majority of injuries, 69.6 percent (fig. 16). When only American troops are considered, this proportion rises to 82 percent.

Involvement of viscera.—Almost three-quarters of these injuries involved only abdominal viscera (table 6). The remaining 839 wounds were thoraco-abdominal.

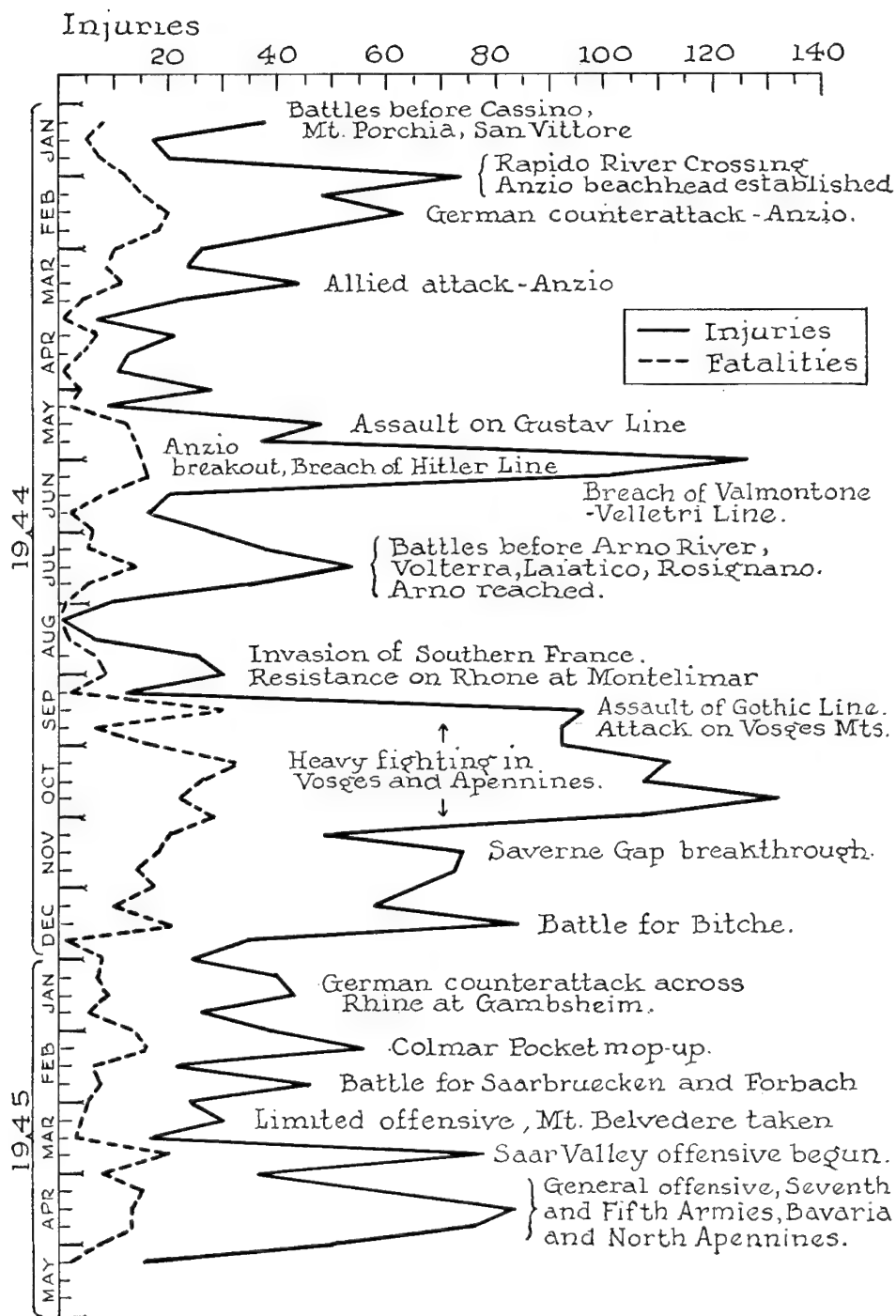


FIGURE 15. (See opposite page for legend.)

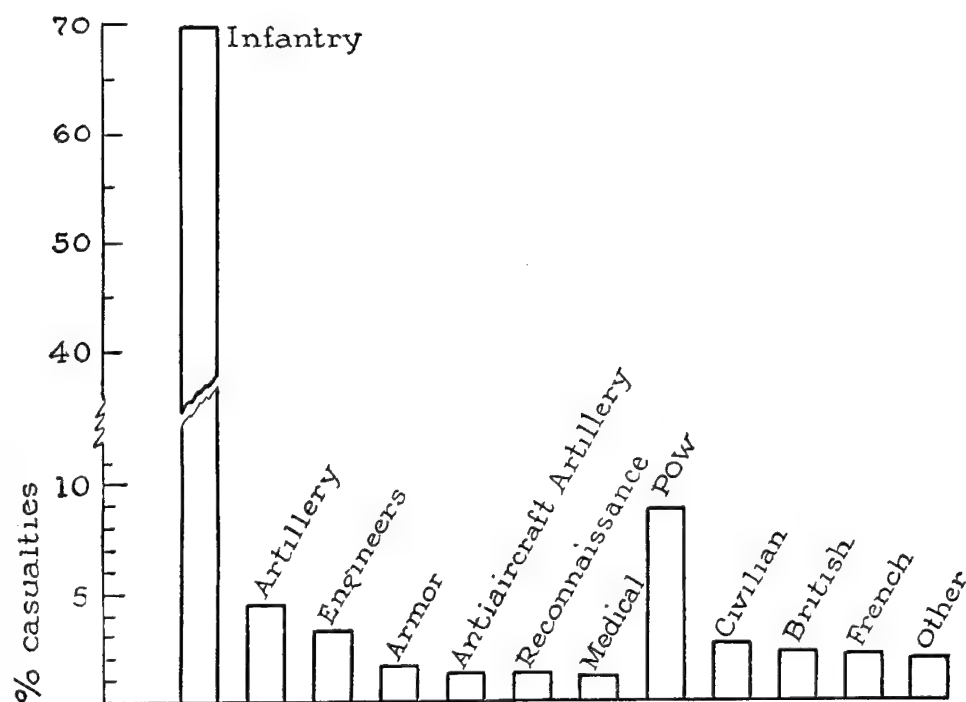


FIGURE 16.—Proportional distribution, according to branch of service, of 2,137 recorded abdominal injuries.

TABLE 6.—Regional distribution of wounds and deaths in 3,154 abdominal injuries

Type of wound	Year	Cases	Deaths	Case fatality rate
Abdominal.....	1944	1,744	406	23.3
Thoracoabdominal.....	1944	639	180	28.2
Abdominal.....	1945	571	130	22.8
Thoracoabdominal.....	1945	200	40	20.0
Total abdominal wounds.....	1944-45	2,315	536	23.2
Total thoracoabdominal wounds.....	1944-45	839	220	26.2
Total.....		3,154	756	24.0

FIGURE 15.—Shown in the graph on the facing page is the distribution in relation to intensity of combat of the 3,154 abdominal injuries which are the source material of part II of this volume. These 3,154 injuries (casualties), including 756 fatalities, were sustained in the 1944-45 campaigns in Italy, southern France, and Germany.

Analysis of these 3,154 abdominal injuries from the standpoint of the particular viscera involved (tables 7 and 8) suggests that the frequency of wounding of an abdominal organ was almost directly proportional to its size. The frequency of univisceral wounds of any given organ was apparently proportional to the extent of its area of contact with the abdominal wall. In other words, in modern warfare the frequency of wounding of any given abdominal organ seems directly proportional to the space which it occupies. The soundness of this conclusion is evident from a consideration of the agents of wounding in this series (p. 97). About 70 percent of the wounds were produced by fragmentation missiles. The remaining injuries, while they were caused by bullets, were chiefly produced by roughly aimed automatic weapons. A sniper's bullet, no matter how accurate the sighting might be, was not fired with selective intention toward any single abdominal organ. The fact that patients with certain types of injuries were not seen alive is the explanation of variations from the rule that the frequency of wounding of any given abdominal organ was directly proportional to the space which it occupies. A striking example

TABLE 7.—*Distribution of univisceral and multivisceral wounds in 3,154 abdominal injuries*¹

Organ injured	Univisceral		Multivisceral		Total	
	Number	Each organ	Number	Each organ	Number ²	All patients
		<i>Percent</i>		<i>Percent</i>		<i>Percent</i>
Stomach.....	42	10. 1	374	89. 9	416	13. 19
Duodenum.....	2	1. 7	116	98. 3	118	3. 74
Jejuno-ileum.....	353	30. 2	815	69. 8	1, 168	37. 03
Colon only.....	251	23. 6	816	76. 4	1, 067	33. 83
Rectum only.....	64	55. 2	52	44. 8	116	3. 68
Colon and rectum.....	13	33. 4	26	66. 6	39	1. 24
Liver ³	339	40. 9	490	59. 1	829	26. 28
Gallbladder and bile ducts.....	0	0	53	100. 0	53	1. 68
Pancreas.....	1	1. 6	61	98. 4	62	1. 97
Spleen.....	100	29. 3	241	70. 7	341	10. 81
Kidney.....	56	13. 1	371	86. 9	427	13. 54
Ureter.....	1	3. 7	26	96. 3	27	. 86
Urinary bladder.....	21	13. 5	134	86. 5	155	4. 91
Great vessels.....	8	10. 7	67	89. 3	75	2. 38

¹ The term "univisceral" refers to an abdominal wound in which a single viscus has been injured. It carries no implication concerning the number of injuries any single organ has sustained. The term "multivisceral" refers to a wound in which more than 1 viscus has been injured, again without any implications concerning the number of injuries each single organ has sustained.

² The figures in this column considerably exceed the total number of cases because in multivisceral wounds the same patient appears in more than one category. For the same reason, the percentage distribution of wounds in the various viscera exceeds 100 percent.

³ Calculations for injuries of the liver are made throughout part II of this volume on a total of 3,066 abdominal injuries, instead of on 3,154, the base figure for all other calculations. When the 88 histories which represent the difference between the two totals became available, the medical officers who had done the work on wounds of the liver had already been transferred from the command, and it was thought wiser not to change their tabulations.

TABLE 8.—Comparative percentages of univisceral and multivisceral injuries in various recorded series of abdominal wounds¹

Series	Organ injured	Total	Univisceral	Multivisceral
		<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
World War I:				
American.....	Stomach.....	7.0	66.7	33.3
British.....	do.....	8.5	68.3	31.7
Spanish Civil War.....	do.....	8.4	(?)	(?)
World War II:				
British ²	do.....	4.6	48.2	51.7
2d Auxiliary Surgical Group.....	do.....	13.2	10.1	89.9
World War I:				
American.....	Jejunum-ileum.....	22.0	(?)	(?)
British.....	do.....	37.6	70.3	29.7
Spanish Civil War.....	do.....	31.5	(?)	(?)
World War II:				
British ³	do.....	32.9	56.8	43.2
2d Auxiliary Surgical Group.....	do.....	37.0	30.2	69.8
World War I:				
American.....	Colon.....	22.0	(?)	(?)
British.....	do.....	(?)	60.0	40.0
Spanish Civil War.....	do.....	21.4	(?)	(?)
World War II:				
British ³	do.....	25.5	65.6	34.4
2d Auxiliary Surgical Group.....	do.....	33.8	23.6	76.4
World War I:				
American.....	Liver.....	13.3	75.0	25.0
British.....	do.....	16.8	90.8	9.2
Spanish Civil War.....	do.....	15.9	(?)	(?)
World War II:				
British ⁴	do.....	14.2	85.7	14.3
2d Auxiliary Surgical Group.....	do.....	26.3	40.9	59.1
World War I:				
American.....	Spleen.....	1.4	33.3	66.7
British.....	do.....	⁵ 5.6	59.3	40.7
Spanish Civil War.....	do.....	4.6	(?)	(?)
World War II:				
British ⁴	do.....	4.9	75.0	25.0
2d Auxiliary Surgical Group.....	do.....	10.8	29.3	70.7
World War I:				
American.....	Kidney.....	6.3	50.0	50.0
British.....	do.....	7.6	(?)	(?)
Spanish Civil War.....	do.....	8.0	(?)	(?)
World War II:				
British ⁴	do.....	4.0	70.0	30.0
2d Auxiliary Surgical Group.....	do.....	13.5	13.1	86.9

¹ The American percentages for World War I are derived from The Medical Department of the United States Army in the World War. (Washington: U. S. Government Printing Office, 1927. See vol. XI, pt. 1, pp. 65, 446-465). The British percentages for World War I are from War Surgery of the Abdomen, by Cuthbert Wallace (London: J. & A. Churchill, 1918). The percentages for the Spanish Civil War are based on a series of 238 cases recorded by Douglas W. Jolly (see p. 169 of Field Surgery in Total War, New York: Paul B. Hoeber, Inc., 1941). The British percentages for World War II are derived from two series reported by W. H. Ogilvie in Abdominal Wounds in the Western Desert (see Surgery, Gynecology and Obstetrics, 78: 225-238, March 1944).

² Not stated.

³ Western Desert combined series (628 cases).

⁴ Western Desert second series only (247 cases).

⁵ Estimated.

of such a variation is the comparative incidence of wounds of the vena cava and of the abdominal aorta (pp. 318, 322). Thirty-three of the former were observed, but none of the latter, presumably because wounds of the abdominal aorta were almost immediately fatal.

When the distribution of abdominal visceral injuries in this series is compared with the distribution in other reported series (table 8), two important differences are at once apparent:

1. In general, the frequency of wounding of all organs was higher in this series than in most other series.

2. The rate of univisceral to multivisceral wounds was strikingly reversed in comparison with earlier experiences. The assumption seems warranted that in this series a much higher proportion of severely wounded men (that is, men with multiple visceral wounds) reached forward hospitals, and were operated on, than was the case in other reported series. No other explanation seems reasonable for the overall increase in frequency of wounding of all organs, or, more particularly, for the marked change in the multivisceral-univisceral ratio. The higher incidence of involvement of the various viscera in this series also makes it reasonable to assume that while the figures probably are still too low, they more closely approximate the true frequency of wounding of each organ than do those previously reported.

That so many more of the seriously wounded casualties were seen at forward hospitals in World War II than in previous wars is difficult to explain, except on the basis of the efficient performance of medical echelons working forward of these hospitals and responsible for the evacuation of the wounded from the frontlines.¹

CASE FATALITY RATES

In 1944, surgeons of the 2d Auxiliary Surgical Group treated 2,383 abdominal injuries in forward hospitals supporting the Fifth and Seventh United States Armies, with 586 recorded deaths (24.6 percent). In 1945, they treated 771 similar injuries, with 170 recorded deaths, 22.0 percent. The case fatality rate for the whole series of 3,154 injuries was thus 24.0 percent (table 6).

Two things must be emphasized in this connection:

1. These 756 deaths, as already pointed out, include only those known to have occurred in the forward hospitals in which initial surgery was performed. The postoperative stay in these hospitals seldom exceeded 14 days and was frequently briefer. Additional deaths undoubtedly occurred in installations farther to the rear, though since no followup of the patients was possible, the exact number is not known. Informal inquiries indicated that fatalities in these hospitals did not exceed 1 percent.

¹ NOTE.—Col. (later Maj. Gen.) Joseph I. Martin, MC, surgeon, Fifth U. S. Army, for many years had taught the principles of medical evacuation in forward areas of combat at the Medical Field Service School, Carlisle Barracks, Pa. During combat in Italy, where many of these casualties occurred, he not only placed hospitals as far forward as tactically feasible but also demanded and obtained early and efficient medical evacuation under most difficult combat conditions.—J. B. C., Jr.

2. It is highly probable that more than 756 deaths occurred in forward installations. The records of 256 patients contained no note at all concerning their postoperative progress, and in 81 other cases progress notes ceased after the third postoperative day. These data were lacking chiefly because of forced movement of surgical teams or early evacuation of patients under difficult tactical circumstances. In the completely recorded cases, the case fatality rate after the third day was 4.6 percent. If it is assumed that the rates in the 337 incompletely recorded cases just mentioned were the same as in the completely reported cases, there would have been 65 additional deaths. The total number of fatalities would thus be raised to 821 and the gross case fatality rate to 26.0 percent.

The case fatality rates require explanation from still another standpoint. Included in the series are 333 cases, 10.6 percent of the total, in which no visceral injury was found. In 41 of these cases, the indication for exploration was penetration of the peritoneal cavity by the missile. In the other 292 cases, the indication was suspected penetration of the cavity. In 59 of these explorations, a retroperitoneal hematoma was found. In the remaining cases, the exploration was entirely negative.

There were 24 deaths, 7.2 percent, in these 333 negative explorations, 2 of them in the category of penetration of the peritoneal cavity without visceral injury. These deaths were, for the most part, the result of associated wounds (p. 117). When the 333 cases in which there was no visceral injury are deducted from the total number of cases, there remain 2,821 cases, 732 of which (25.9 percent) were fatal.

In assessing the relative distribution and lethality of wounds of solid and hollow viscera, the analysis, for obvious reasons, must be limited to univisceral injuries. In 496 univisceral injuries of solid viscera, there were 55 deaths (11.1 percent). In 734 similar injuries of hollow viscera, there were 128 deaths (17.4 percent), the case fatality rate thus being 56.7 percent higher than for injuries of solid viscera.

CHAPTER VI

Wounding Agents

*Luther H. Wolff, M. D., Samuel B. Childs, M. D., and
W. Philip Giddings, M. D.*

Of the 3,154 abdominal injuries which make up this series, 3,052, or 96.8 percent of the total, were caused by missiles of war (fig. 17). High-explosive fragments of various types caused 2,123 of these 3,052 wounds (69.6 percent), 1,844 of this group being caused by artillery-shell fragments. The remaining 929 wounds were caused by missiles discharged from small arms. Probably many of the wounds listed in the records as caused by shell fragments were actually the result of mortar fire. The case fatality rate for bullet wounds was 24.7 percent and for high-explosive fragments 23.1 percent.

Wounds of entry and exit.—The experience in this large series of injuries made it clear that the effects of a given type of missile are by no means uniform. It was generally true, for instance, that the wound of entry was smaller than the wound of exit, but cases were observed in which the wound of exit was the smaller. The wound of exit was always the smaller when a slender fragment which presented its greatest diameter at the site of entry made its exit along a path parallel to its long axis.

In the 2,586 abdominal injuries in which data concerning the site of entry and of exit of the wounding agent were accurately recorded (fig. 18), the missiles entered anteriorly in 1,228 cases (47.5 percent), posteriorly in 730 (28.2 percent), and laterally in 617 (23.9 percent). Three hundred and forty-one wounds of entry (13.2 percent) were in the buttocks or the region of the hips, and 11 (0.4 percent) were in the perineum.

The wounds were distributed almost equally between the right and left sides of the body. Excluding the 151 wounds in the midline and the 11 in-

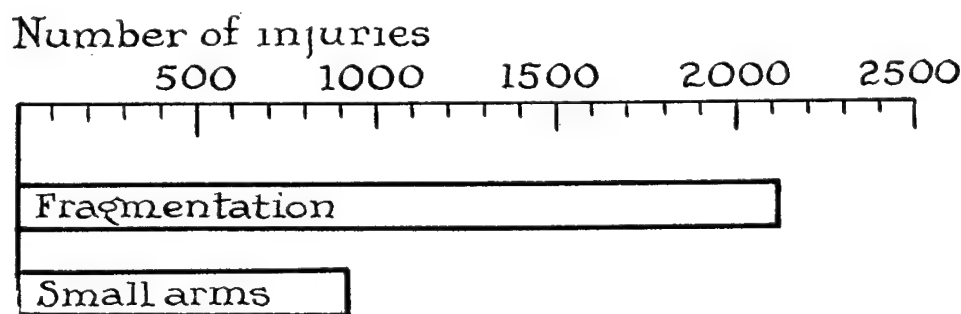


FIGURE 17.—Distribution of causative missiles in 3,052 abdominal injuries.

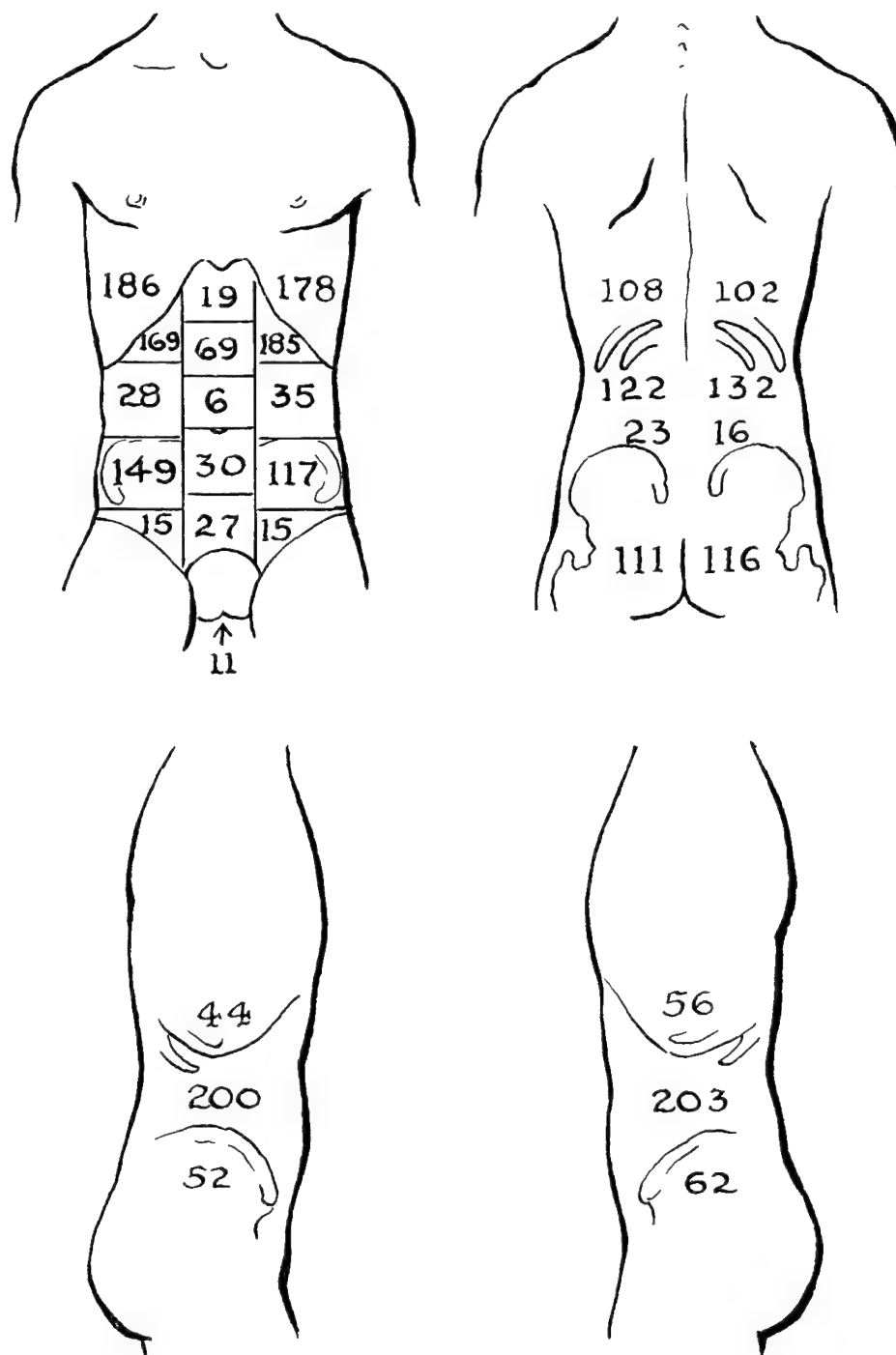


FIGURE 18.—Anatomic distribution of wounds of entry in 2,586 recorded abdominal injuries.

stances in which the wound of entry was through the perineum, there were 1,209 wounds on the right side and 1,215 wounds on the left side.

The most significant discrepancy in the distribution of the wounds of entry is the much larger number of anterior than posterior wounds. For this there are two possible explanations, aside from the obvious reason that the casualties were part of an advancing army:

1. The greater thickness of the musculature of the back, combined with the presence of the bony spine, tended to afford more protection against injury than did the anterior abdominal wall.

2. Soldiers carrying field packs on their backs had some additional protection from them, especially against low-velocity missiles.

On the other hand, a certain number of posterior wounds are to be expected. Combat soldiers, while advancing, are often pinned to the ground, and many times lie prone, thus exposing posterior portions of the body and making them readily accessible to exploding agents of war.

Tracks of missiles.—Clinical observations suggest that the possibility of tracks of missiles not following a straight line has been greatly overemphasized in the past. In practically every instance in this series, the course of the missile within the body was a straight line. Bizarre or circuitous tracks were extremely uncommon.¹ A seemingly erratic course could almost invariably be explained by an accurate reconstruction of the position of the soldier when he was struck (fig. 19). Changes of posture caused significant displacement of viscera and altered their customary relationships.

In no instance in the series did a missile traverse a major diameter of the abdomen without causing visceral injury.

Effects of missiles.—Clinically, effects of the missiles were of extraordinary variability, the results apparently being related to the size of the fragment, which was usually roughly proportional to the caliber of the shell; its shape; and the distance of the soldier from the site of the explosion. This distance served as a rough index of the velocity of the missile. Explosive, concussive effects were more frequently observed in casualties injured at close range than in those at a distance from the shell burst. Jagged, lacerated, irregular wounds were, in general, more frequently caused by shell fragments than by missiles from small arms, but there were many exceptions to this generalization. In some instances, large fragments or multiple smaller fragments produced by a shell burst close at hand destroyed large parts of the abdominal parietes or even carried away the entire flank; casualties with injuries of this kind seldom survived to reach the hospital.

Wounds caused by mortar fragments, especially at close range, were often characterized by the presence of multiple small fragments which were slight in mass but which had entered the body at high velocity. These fragments apparently decelerated rapidly on impact; though they penetrated the abdomen,

¹ One interesting case of this kind is personally known to the editor in chief. The surgical consultant, Office of the Surgeon, Headquarters, Third U. S. Army, was wounded by a sniper in France. The bullet struck the left anterior chest of this officer, fractured a rib, followed the rib path laterally and posteriorly, and lodged beneath the left scapula.

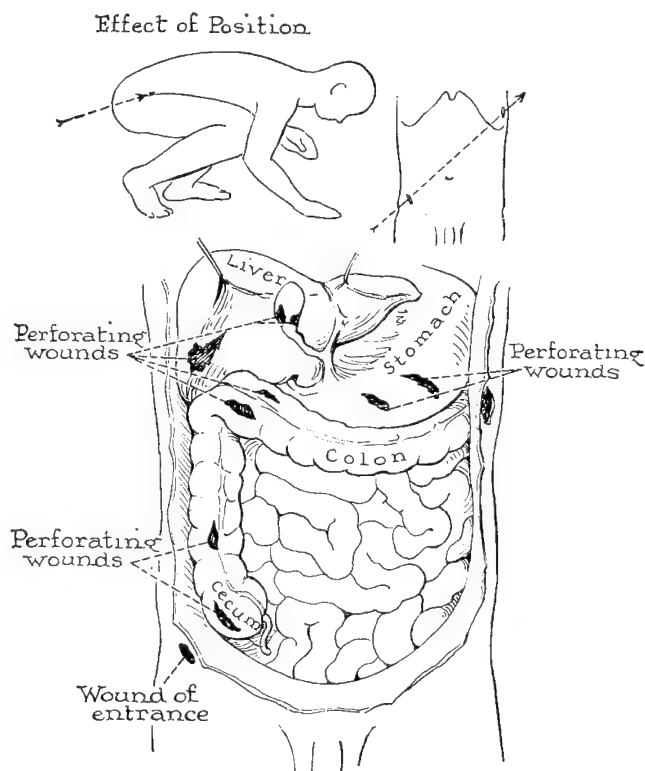


FIGURE 19.—Possible effect of position on track of missiles and resulting visceral injuries.

they seldom caused perforating (through-and-through) wounds. Roentgenologic examination of casualties who were literally peppered with tiny holes showed the penetration of the skin by hundreds of small fragments. Tissue destruction of an almost unbelievable extent was sometimes found below the cutaneous wounds, because each fragment had imparted all of its kinetic energy to the tissue through which it had passed. It was impossible in such cases even to localize all the fragments accurately, let alone to remove them.

Wounds caused by rifle fire were usually single. Wounds from German machineguns or machine pistols were usually multiple, because these weapons fired at a very rapid rate. The destructive effect of small-arms missiles on the tissue was often similar to the effect of high-explosive fragments. When bullets struck perpendicularly, they often caused small, clean perforations. When their impact was tangential, they produced large lacerations and even concussive rupture of viscera. Their effects, which were frequently multiple, depended upon velocity as well as upon angle of impact, as the following case history shows:

Case history.—A German prisoner of war was wounded at a range of about 20 yards by a caliber .30 bullet from an American carbine, when the missile was in the initial phase

of high velocity. The wound of entry was in the left midaxilla, and the wound of exit was through the symphysis pubis on the same side. The missile caused a 5-mm. perforation of the diaphragm, with only slight contusion, and a gutter wound of the lateral margin of the left kidney. Its concussive effect was such, however, that the entire kidney was split wide open to the uretero-pelvic junction. Two small through-and-through perforations of the jejunum resulted from the perpendicular impact of the bullet, while in other portions of the bowel its tangential impact produced mangled perforations and lacerations. The bullet also passed through the bladder, leaving a large, explosive wound of entry and a small, clean wound of exit.

In wounds caused by armor-piercing bullets of small caliber, the jacket, which was usually shed by the projectile, sometimes acted as a secondary missile. The trauma produced by the steel core was similar to that caused by a bullet with an ordinary lead core, but the jacket, because of its ragged contour, was often mistaken roentgenologically for a shell fragment. Bullets which ricocheted were usually distorted, and the jacket was usually partially separated at the base. The tearing effect of such missiles was often extremely destructive.

Mine fragments, nearly all from the German "S-mine" or "Bouncing Betty," caused a small number of abdominal wounds. The characteristic missiles from these mines were steel balls (shrapnel) and small, machine-cut steel cylinders. Their effects were essentially the same as those of shell fragments.

Dirt, stones, occasionally bits of impedimenta carried in the pocket, pieces of identification tags, and bone fragments were encountered as secondary missiles. Of these, bone fragments were the most destructive. In a large number of the 238 cases in this series in which fractures of the pelvis occurred in association with abdominal wounds, the forcible irruption of spicules of bone into the peritoneal cavity caused perforations of both the large and the small intestine, particularly the cecum. A similar effect was observed when missiles entered the peritoneal cavity through the spine.

Ruptures of the intraperitoneal viscera were occasionally associated with injuries in which the peritoneum was not penetrated. Injuries of this kind were apparently caused by missiles of extremely high velocity and great concussive power (p. 331).

The extent of tissue destruction caused by the various missiles used in World War II, particularly by artillery-shell fragments, at times almost passed belief. Intestines were often found shredded into ribbons, and solid viscera often seemed to have exploded, with completely detached pieces of liver, spleen, or kidney being observed free in the peritoneal cavity. The destructiveness of the missiles employed in World War II is impossible to overemphasize. Nothing seen in civilian surgery even remotely approaches the extent of the trauma associated with the wounds encountered in this war.

CHAPTER VII

Timelag and the Multiplicity Factor in Abdominal Injuries

*Luther H. Wolff, M. D., W. Philip Giddings, M. D.,
Samuel B. Childs, M. D., and Clarence R. Brott, M. D.*

At the beginning of World War II, as in previous wars, it was a universally accepted concept that the length of the timelag (the interval from wounding until the institution of therapy) had an important influence on the case fatality rate in abdominal wounds. On the surface, this is a perfectly reasonable point of view. Hemorrhage, peritoneal contamination, and disturbances of cardio-respiratory and gastrointestinal physiology combine to produce a state of shock following wounding. The longer these conditions are permitted to continue uncorrected, the more severe does the shock become, the more serious is the deterioration of the wounded man's status, and, presumably, the graver is the prognosis.

It was with full acceptance of this concept that the analysis was undertaken of the 2,926 abdominal injuries in this series in which data concerning the timelag were available. The average interval from wounding to operation was found to be almost 10.5 hours, the two components being, respectively, 6.5 hours for the period from injury to hospitalization and 3.9 hours for the period from hospitalization to operation. The chief obstacle to earlier hospitalization lay in the obvious difficulties in evacuating casualties from the battlefield. The delay in the hospital was more apparent than real; it was explained by the time consumed in necessary preoperative resuscitation, particularly of poor-risk patients. A further explanation, in times of stress, was the overburdening of available surgical facilities, which resulted in an inevitable prolongation of the timelag.

All through the war, every possible effort was directed toward shortening the timelag, in line with the belief that the earlier operation could be performed, the better would be the results, and vice versa. As the result of these efforts, and as the experience of military personnel increased and evacuation facilities were improved, a substantial reduction in the average timelag was achieved. In 1944, it was 11.4 hours (6.9 hours between wounding and hospitalization and 4.5 hours between hospitalization and operation). In 1945, it was reduced to 9.5 hours (6.1 hours between wounding and hospitalization and 3.4 hours between hospitalization and operation).

In view of these facts, it was therefore disconcerting, when this analysis was conducted after the war, to find that the figures furnished little support for the concept that the length of the timelag had an important influence on the case fatality rates. When they were calculated in 2-hour periods (fig. 20), no



FIGURE 20.—Influence of timelag (wounding to operation) in 2,863 recorded abdominal injuries. Sixty-three cases in which the timelag was greater than 36 hours are not included, because the number would have been too small in each category over 36 hours to be of significance.

consistent change in them was observed with the passage of time. Obviously it was necessary to seek an explanation for the paradox that an increase in the timelag did not greatly increase the case fatality rate, while a shortening of the interval did not greatly improve it.

When the abdominal wounds in the series were evaluated in terms of their severity, the apparent paradox was promptly resolved. An analysis from this point of view showed that wounds of the same viscus differed from casualty to casualty in respect to their extent, the degree of associated hemorrhage, the amount of peritoneal contamination, and the specific effect of the wound upon

the individual. On the other hand, in spite of their evident importance, these considerations could not be reduced to statistical form. From these standpoints, each case was an entity in an exclusive category.

As a practical solution of the problem, therefore, these abdominal injuries were classified from the standpoint of severity in terms of the number of visceral injuries each individual casualty had sustained. When this had been done, it immediately became clear that whether or not patients who had sustained the greatest number of visceral injuries (and who, presumably, were the most severely wounded) were to live or die did indeed depend in large measure upon the time elapsed between wounding and the institution of surgical care. The most severely wounded patients, in terms of multiplicity of injuries, survived only if they were operated on promptly, and the case fatality rate increased progressively from category to category as the timelag increased (table 9). It was 100 percent in the categories in which the largest number of wounds was associated with the longest timelag. There were no survivals among the 6 casualties who suffered 6 visceral injuries each, although 5 of the 6 were operated on within 16 hours of wounding, and there were only 2 survivals among the 22 patients with 5 visceral injuries each, although 20 of the 22 were also operated on within 16 hours of wounding. It is true that in some of the categories the numbers of cases were so small as to be without statistical significance, but in general the figures corroborated the clinical impression that the least severely wounded man could tolerate a certain prolongation of the timelag, while the most severely wounded men could not. Some wounds were potentially lethal, regardless of the brevity of the timelag, while others were not necessarily lethal originally but tended to become so as the timelag increased.

The truth of the assumption that the case fatality rate increases as the timelag lengthens was generally acceptable for the individual patient, though at the extremes of time there were balancing factors which effectively precluded its demonstration. Many of the fatalities in the first hours after injury occurred in mortally wounded men, who were given priority of treatment in what proved a vain attempt to save their lives. These deaths elevated the case fatality rates for the early hours. At the other extreme of time, patients who survived after 18 to 24 hours without operation might well have lived without treatment; no one would contend that all abdominal wounds are fatal without surgery.

Examination of the multiplicity indexes (table 9) confirms these generalizations. They are, respectively, 1.64, 1.59, 1.45, 1.41, and 1.13. By these criteria, the most severely wounded patients obviously were operated on in the first 8-hour interval, and the least severely wounded were operated on after 24 hours. The figures thus afford statistical confirmation of a recognized clinical observation; namely, the case fatality rate in casualties operated on early was elevated by the inclusion in this category of a relatively large number of the most critically wounded casualties, while the rate among those coming to surgery late was kept below expected levels by the inclusion of a similar proportion of the less seriously wounded.

TABLE 9.—*Influence of combined timelag and multiplicity factor on case fatality rates in 2,926 abdominal injuries*

Organs injured	Timelag (wounding to operation, in hours)														
	0 through 8			9 through 16			17 through 24			25 through 36			37 to 90		
	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate
None.....	98	5	5.1	116	9	7.8	34	3	8.8	20	3	15.0	11	2	18.2
One.....	496	50	10.1	519	77	14.8	145	24	16.6	72	19	26.4	36	12	33.3
Two.....	402	97	24.1	391	112	28.6	103	32	31.1	37	11	29.7	13	8	61.5
Three.....	132	56	42.4	144	67	46.5	24	12	50.0	14	7	50.0	3	1	33.3
Four.....	41	22	53.7	38	25	65.8	7	6	85.7	2	1	50.0	0	0	-----
Five.....	13	12	92.3	7	6	85.7	1	1	100.0	1	1	100.0	0	0	-----
Six.....	3	3	100.0	2	2	100.0	0	0	-----	1	1	100.0	0	0	-----
Total.....	1,185	245	20.7	1,217	298	24.5	314	78	24.8	147	43	29.3	63	23	36.5
Multiplicity index	1.64			1.59			1.45			1.41			1.13		

MULTIPLICITY FACTOR

Since the importance of the multiplicity of visceral injuries was an entirely new concept in military surgery, a new nomenclature had to be devised for it. The terms "multiplicity factor" and "multiplicity index" were accordingly introduced. Multiplicity factor was employed to designate the number of abdominal organs injured in any given patient, as determined at operation or autopsy. Multiplicity index was employed to indicate the aggregate severity of the individual cases in a given series of abdominal wounds. It was obtained by dividing the total number of organs injured in the series by the number of cases which made up the series.

In the interests of clarity, certain explanations are necessary in regard to this nomenclature. Multiplicity factor does not imply selectivity of viscera. Combinations are limited entirely to numerical incidence. Only the number of organs injured matters. Nor does the term carry any implications concerning the total number of wounds sustained in a given case, since multiple wounds of the same viscus are counted as a single wound. Thus, wounds of the cecum, transverse colon, and sigmoid colon in the same patient would be counted as a single wound of the large bowel, and wounds of the jejunum and ileum would be counted as a single wound of the small bowel.

In this analysis, wounds of the major abdominal blood vessels (as distinguished from wounds of the visceral blood supply) are not regarded as visceral injuries. It is evident, however, that the multiplicity factor is just as valid in them as it is in other abdominal injuries (p. 323), the only difference being that the case fatality rates for vascular injuries begin at a much higher level.

It should be emphasized again that the concept of the multiplicity factor was a *postwar* development. It was evolved only when it became evident that the timelag, upon which the major emphasis had been placed in the past, apparently did not play the role in the case fatality rate in abdominal injuries which it was formerly supposed to play. When the multiplicity factor was adopted as a yardstick in the analysis, much that had been contradictory and confusing when the timelag alone was used as a point of reference was immediately clarified. It now became clear that, when only the timelag was analyzed, dissimilar cases were being compared with each other and that the analysis of this type of trauma would be valid only when the cases were separated into comparable and exclusive categories.

When the injuries in which sufficient data for this purpose were available were categorized according to the multiplicity factor (tables 9 and 10, figs. 21 and 22), the timelag fell into the proper perspective, the case fatality rate was found to ascend in almost arithmetical progression with each additional viscus injured, and the increase was almost as constant for each special organ as it was for the entire series.

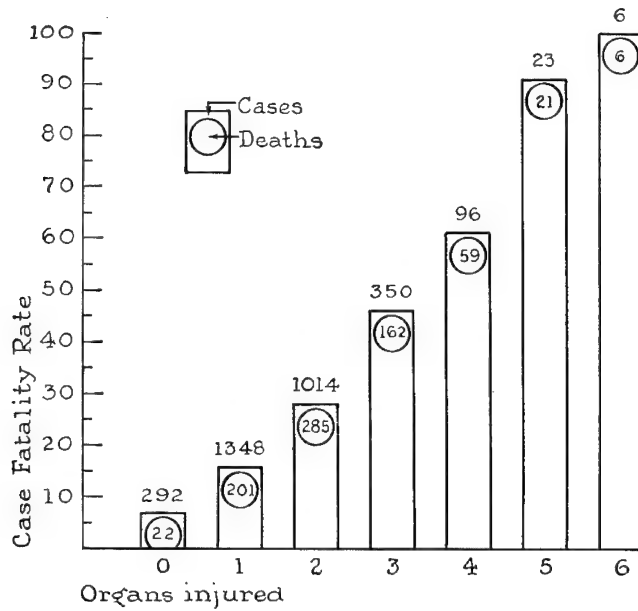


FIGURE 21.—Influence of multiplicity factor on case fatality rates in 3,129 recorded abdominal injuries.

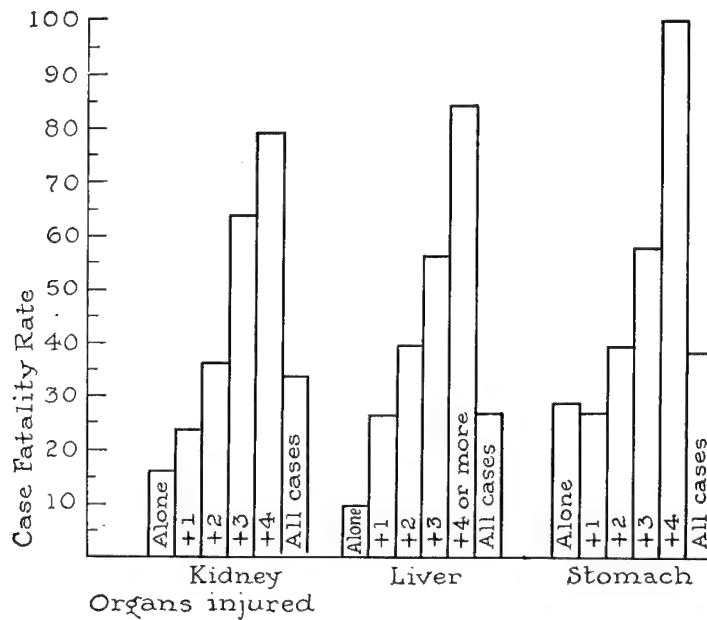


FIGURE 22.—Influence of multiplicity factor on case fatality rates in various combinations of abdominal wounds.

TABLE 10.—*Influence of multiplicity factor on case fatality rates in wounds of various viscera*

Organs injured	Cases	Deaths	Case fatality rate
Stomach: ¹			
Alone.....	42	12	28.6
With 1 other viscus.....	174	47	27.0
With 2 other viscera.....	112	44	39.3
With 3 other viscera.....	50	29	58.0
With 4 other viscera.....	23	23	100.0
Total.....	401	155	38.7
Liver:			
Alone.....	339	33	9.7
With 1 other viscus.....	238	63	26.5
With 2 other viscera.....	151	60	39.7
With 3 other viscera.....	62	35	56.5
With 4 (and more) other viscera.....	39	33	84.6
Total.....	829	224	27.0
Kidney:			
Alone.....	56	9	16.1
With 1 other viscus.....	172	41	23.8
With 2 other viscera.....	105	38	36.2
With 3 other viscera.....	47	30	63.8
With 4 other viscera.....	24	19	79.2
Total.....	404	137	33.9

¹ There are omitted from this category 15 cases in which wounds of the stomach and one or more other viscera were complicated by wounds of the great vessels.

The multiplicity factor also proved a valuable aid in the appraisal of abdominal injuries from a number of other points of view:

1. *Associated injuries.*—An analysis of the 1,089 cases in which abdominal wounds were associated with extra-abdominal wounds (p. 114) revealed that moderately severe extra-abdominal injuries were often associated with abdominal wounds of high multiplicity and that the reverse was also true, severe extra-abdominal injuries usually being associated with abdominal injuries of low multiplicity. The statistics suggested that when severe extra-abdominal injuries were associated with abdominal injuries of high multiplicity, the wounded men seldom survived to reach the hospital.

2. *Shock.*—Virtually every one of the deaths which occurred in this series within the first 24 hours after operation was attributable to shock, which developed as the result of hemorrhage, peritoneal contamination, or tissue destruction. As might have been expected, a definite association was found to exist between the multiplicity factor and these deaths. In the 756 fatalities in the whole series, 35 percent of the deaths in univisceral wounds occurred within 24

hours of operation, as did 36 percent of the deaths in which 2 organs were injured, 40 percent of the deaths in which 3 organs were injured, and 51 percent of the deaths in which 4 or more organs were injured.

3. *Pulmonary complications.*—The incidence of postoperative pulmonary complications (p. 204) rose from 6.5 percent in univisceral injuries to 13.0 percent when 5 or more viscera were injured. This observation is of clinical rather than statistical significance. The more severely wounded patients were more apt to develop stagnation of the tracheobronchial secretions and therefore presented a higher incidence of atelectasis and bronchopneumonia.

4. *Variations in case fatality rates.*—One of the perplexing features of this analysis before the concept of the multiplicity factor was evolved was the differences between the case fatality rates of surgeons of equal ability and experience. Another was the differences between the rates of more forward (field) hospitals and evacuation hospitals. These differences had been realized in the course of the war. They could not reasonably be explained on the basis of superior or inferior surgical performance, or merely as matters of chance. It was the general impression that less severely wounded patients were treated at evacuation hospitals, but proof of the impression was lacking until this series was analyzed on the basis of the multiplicity factor. When the severity of the wounds was taken into consideration, differences in the case fatality rates of hospitals in different echelons (table 5, p. 89) could easily be explained. A high rate was to be expected in field hospitals, because the most severely wounded patients were treated in them.

A single comparison will make this point clear. The case fatality rate for 232 casualties treated by surgeons of the 2d Auxiliary Surgical Group in evacuation hospitals was 15.1 percent, while the rate for surgeons of the same group for 2,851 casualties treated in field hospitals was 24.3 percent. Differences in the multiplicity indexes explain the differences in the case fatality rates. The index for the casualties treated in evacuation hospitals was 1.10, while for casualties treated in field hospitals it was 1.70. Likewise, differences in the multiplicity indexes explain differences in the case fatality rates of surgical teams of similar ability and experience.

<i>Team</i>	<i>Multiplicity index</i>	<i>Case fatality rate</i>
A-----	1. 42	21
B-----	1. 58	23
C-----	1. 63	25
D-----	1. 71	25
E-----	1. 73	27
F-----	1. 80	28

Application of the multiplicity index to certain recorded series of abdominal injuries permitted comparison of them by a uniform standard of evaluation (table 11). An examination of the Welch and Tuhy¹ series, the Ogilvie (Western Desert)² series, and the material of the 2d Auxiliary Surgical Group

¹ Welch, C. S.; and Tuhy, J. E.: Combined Injuries of the Thorax and Abdomen. *Ann. Surg.* 122: 358-374, September 1945.

² Ogilvie, W. H.: Abdominal Wounds in the Western Desert. *Surg., Gynec. & Obst.* 78: 225-238, March 1944.

shows the correlation which might be expected between the Welch and Tuhy figures and those of the 2d Auxiliary Surgical Group. In the British material, on the other hand, although the multiplicity index was lower than in either of the other series, the case fatality rate was higher. The discrepancy can probably be explained by two factors: (1) That conditions of evacuation and hospitalization were frequently extremely unfavorable in the fighting in the Western Desert, and (2) that penicillin was not available when these cases were treated as it was for the patients in the other (later) series.

TABLE 11.—*Influence of multiplicity factor on case fatality rates in various recorded series of abdominal injuries*

Organs injured	Welch and Tuhy series		British World War II series ¹		2d Auxiliary Surgical Group series	
	Cases	Case fatality rate	Cases	Case fatality rate	Cases	Case fatality rate
None.....	5	20.0	42	23.8	292	7.5
One.....	44	11.3	164	31.1	1,348	14.9
Two.....	17	29.4	31	48.4	1,014	28.1
Three.....	3	33.3	² 7	71.3	350	46.3
Four.....	1				96	61.5
Five.....					23	91.3
Six.....					6	100.0
Total.....	70	17.1	244	33.2	3,129	24.2
Multiplicity index.....	1.30		1.02		1.58	

¹ Western Desert (second series, 244 cases; 3 deaths on the operating table are excluded from the figures).

² In this category are included all injuries of 3 or more organs.

LIMITATIONS OF THE MULTIPLICITY FACTOR

In this series of abdominal injuries, the application of the multiplicity factor clarified much that had originally been confusing and actually inexplicable. On the other hand, while it proved to be of a valuable statistical type for series analysis, it was found to have certain weaknesses and limitations, because of relative dispersion, when it was applied to individual cases. Another reason was that it was entirely possible for a wound of a single viscus to be so grave that the intra-abdominal damage was as serious as it was in another case in which three or even more organs were wounded. Thus the multiplicity factor was found to be not completely reliable in wounds of the stomach (table 10, fig. 22). In injuries of this organ, the case fatality rate for univisceral wounds was slightly higher than for gastric wounds complicated by a wound of one other viscus. The explanation is the inherent gravity of all wounds of

the stomach, which were likely to be associated with acute precipitous chemical peritonitis (p. 231). For this reason, the case fatality rate in univisceral gastric wounds was unusually high as compared with the rates for univisceral wounds of other organs.

On the surface, it might seem that the multiplicity factor should be useful in prognosis, making it possible to predict the outcome for the individual casualty with a reasonable degree of accuracy. In general (fig. 21), the case fatality rate increased about 15 percent as each additional viscus was injured, and, generally speaking, the number of viscera injured was more significant than the particular organ involved. These generalizations, however, do not hold for the individual case, in which the multiplicity factor must be used with great caution. For one thing, in a case in which only one or two viscera are injured, an unusually prolonged timelag might make the prognosis more serious than the multiplicity factor alone would indicate. For another, the presence of serious associated extra-abdominal injuries, the development of anaerobic and other infections, unforeseen complications such as intestinal obstruction and wound dehiscence, and other considerations of the same sort might completely vitiate the multiplicity factor in the individual case.

Notwithstanding the variations and limitations of the multiplicity factor in its application to individual cases, when it was applied to this particular series—in which many variables existed—it supplied an accurate and useful yardstick for many different purposes and resolved at once the apparent paradox which had existed when the case fatality rates were calculated only in reference to the timelag.

CHAPTER VIII

Associated (Extra-Abdominal) Wounds (1,089 Casualties)

Leigh K. Haynes, M. D., and Floyd D. Taylor, M. D.

In addition to the 839 thoracoabdominal wounds in this series of 3,154 abdominal injuries, associated (extra-abdominal) wounds of significant severity occurred in 1,089 cases (47.0 percent). Two hundred and sixty-two of these were fatal (table 12).

TABLE 12.—*Percent of casualties with and without associated wounds in 2,315 abdominal injuries, with case fatality rates*¹

Abdominal wounds	Cases	Frequency	Deaths	Case fatality rate
		<i>Percent</i>		
Without associated wounds.....	1, 226	53. 0	272	22. 2
With associated wounds.....	1, 089	47. 0	262	24. 1
Total.....	2, 315	100. 0	534	23. 1

¹All thoracoabdominal wounds in the series are excluded from these calculations.

The associated wounds in these 1,089 casualties numbered 1,551, but data suitable for analysis were available for only 1,403 (table 13). Fractures were the most frequent type of associated injury, and the bony pelvis was the most frequent site of fracture (table 14).

TABLE 13.—*Distribution according to type of 1,403 individual associated wounds in 1,089 casualties with abdominal injuries*

Type of wound	Number of wounds	Proportion
		<i>Percent</i>
Fracture (compound).....	659	47. 0
Soft tissue.....	531	37. 8
Thoracic.....	101	7. 2
Spinal cord.....	40	2. 9
Maxillofacial and neck.....	20	1. 4
Major vascular.....	18	1. 3
Major amputation.....	18	1. 3
Peripheral nerve.....	10	. 7
Brain.....	6	. 4
Total.....	1, 403	100. 0

TABLE 14.—*Distribution of major fractures (pelvis, femur, and humerus) in 1,403 associated injuries including 659 fractures*¹

Fracture	Cases	Proportion of—	
		1,403 associated injuries	659 fractures
		Percent	Percent
Pelvis.....	238	17. 0	36. 1
Femur only.....	57	4. 1	8. 7
Femur and 1 other major bone.....	33	2. 3	5. 0
Humerus only.....	31	2. 2	4. 7
Humerus and 1 other major bone.....	21	1. 5	3. 2
Total.....	380	27. 1	57. 7

¹ See table 13.

MULTIPLICITY FACTOR

The importance which had been attributed to the multiplicity factor in the general evaluation of the severity of abdominal injuries (p. 105) suggested an analysis of associated injuries from this point of view (tables 15 to 17 inclusive). The results were entirely dissimilar. There was no progressive rise in the case fatality rates (such as practically always had been observed with increases in the multiplicity factor in abdominal injuries) as the number of associated injuries increased. This might perhaps have been expected, in view of the different severity of abdominal wounds and associated wounds. The strikingly high case fatality rate of 39.4 percent in casualties with 3 associated wounds (table 17) could not be explained. Severe associated wounds were unusual in the group of patients with four or more associated injuries, multiplicity rather than severity apparently being the dominant factor in this category. In the 121 cases which make up this group, multiplicity was so extreme that tabulation was not attempted. There were, however, only 27 deaths, 22.3 percent, approximately the same as for the entire series of 1,089 casualties with associated wounds.

Although detailed analysis did not bear out the clinical impression that the presence of severe extra-abdominal wounds materially increased the case fatality rate in abdominal wounds, a comparison of the injuries categorized according to the visceral multiplicity factor (fig. 23) indicated that the rate in each category was definitely increased when the factor of associated wounds was superimposed. Case fatality rates computed on this basis are almost parallel.

TABLE 15.—Case fatality rates in 527 abdominal injuries complicated by 1 associated injury

Type of associated injury	Cases	Deaths	Case fatality rate
Fracture.....	236	40	16.9
Soft tissue.....	182	37	20.3
Thoracic.....	42	14	33.3
Spinal cord.....	28	14	50.0
Maxillofacial and neck.....	13	3	23.1
Major vascular.....	5	2	40.0
Major amputation.....	9	3	33.3
Peripheral nerve.....	6	0	0
Brain.....	6	2	33.3
Total.....	527	115	21.8

TABLE 16.—Case fatality rates in 299 abdominal injuries complicated by 2 associated injuries

Type of associated injuries	Cases	Deaths	Case fatality rate
Two fractures.....	92	21	22.8
Fracture and soft tissue.....	72	13	18.1
Fracture and thoracic.....	19	5	26.3
Fracture and major vascular.....	5	1	20.0
Fracture and spinal cord.....	5	2	40.0
Fracture and amputation.....	6	0	0
Two soft tissue.....	37	8	21.6
Soft tissue and thoracic.....	14	2	14.3
Soft tissue and spinal cord.....	6	1	16.7
Soft tissue and major vascular.....	8	1	12.5
Other combinations.....	35	10	28.6
Total.....	299	64	21.4

When associated wounds were classified, on the basis of all available data, according to whether they were moderate or severe (a difficult and admittedly arbitrary classification), two facts became evident (fig. 24):

1. The frequency of associated injuries of great severity was highest among patients with abdominal wounds of least severity (that is, of low multiplicity).

2. The frequency of associated injuries of least severity was highest among patients with abdominal wounds of greatest severity (that is, of high multiplicity).

TABLE 17.—Case fatality rates in 142 abdominal injuries complicated by 3 associated injuries

Type of associated injuries	Cases	Deaths	Case fatality rate
Three fractures.....	10	1	10.0
Fracture and two soft tissue.....	54	13	24.1
Fracture, soft tissue, and thoracic.....	8	7	87.5
Fracture, soft tissue, and spinal cord.....	1	0	0
Fracture, soft tissue, and peripheral nerve.....	4	1	25.0
Fracture, soft tissue, and maxillofacial.....	3	1	33.3
Fracture, thoracic, and maxillofacial.....	4	2	50.0
Two fractures and thoracic.....	14	9	64.3
Three soft tissue.....	15	9	60.0
Two soft tissue and amputation.....	3	1	33.3
Other combinations.....	26	12	46.2
Total.....	142	56	39.4

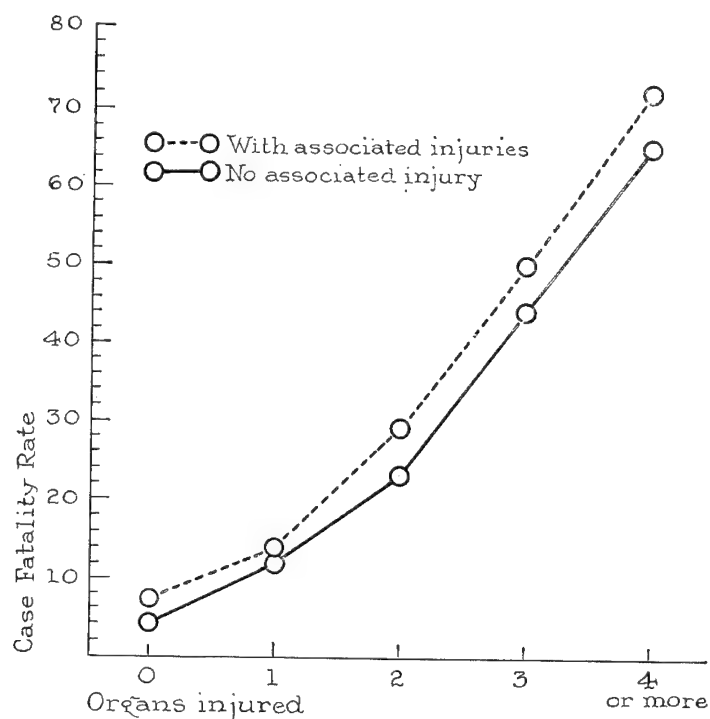


FIGURE 23.—Influence of multiplicity factor and presence of associated injuries in 3,154 abdominal injuries.

These two facts explain why associated wounds in a series of abdominal injuries such as this exerted an apparently minor influence on the overall case fatality rate. The casualties who sustained simultaneously severe abdominal wounds and severe extra-abdominal wounds seldom reached the surgeon alive. Those who survived had severe abdominal wounds associated with mild extra-abdominal wounds or vice versa.

The case fatality rate for casualties with abdominal injuries and associated wounds but without visceral injuries was 7.2 percent (fig. 23), which was lower than for any other category of patients with extra-abdominal injuries. On the other hand, in 19 of the 22 fatal cases in this group, the associated extra-abdominal injuries were severe. The rate among casualties with abdominal injuries but without visceral injuries or associated injuries was 3.8 percent. There seems no doubt that in these combined injuries the fatalities were chiefly a reflection of the severity of the extra-abdominal wounds rather than of the risk of exploratory laparotomy in the absence of visceral damage (p. 95).

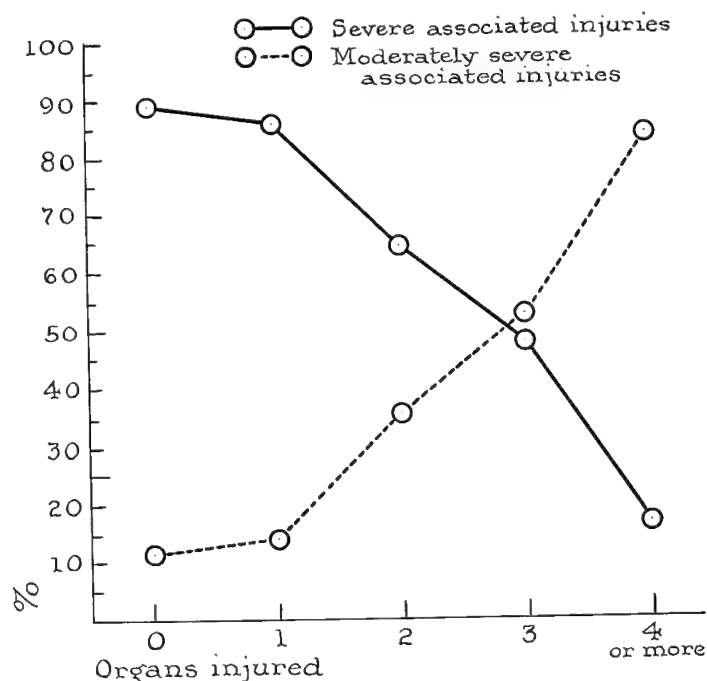


FIGURE 24.—Influence of multiplicity factor and gravity of associated injuries in 3,154 abdominal injuries.

CHAPTER IX

Shock Therapy (957 Casualties)

Beverly T. Towery, M. D., and John D. Welch, M. D.

From the standpoint of the therapy of traumatic shock,¹ soldiers with major wounds of the abdomen presented more serious problems than any other group of casualties. There were a number of reasons:

1. Hemorrhage was frequently massive.
2. Contamination of the peritoneal cavity and retroperitoneal tissues carried the threat of fulminating infection.
3. Concomitant transdiaphragmatic injury of the thorax frequently caused serious disturbances of cardiopulmonary function.
4. These same injuries rendered the pleura liable to contamination by gastrointestinal contents or bile.
5. Multiple visceral and vascular injuries, which were common, often created surgical problems of great technical difficulty, with the result that the duration of anesthesia and operation was necessarily prolonged and further blood losses were likely to occur.

The problem of traumatic shock is considered in detail elsewhere in these volumes.² Resuscitation therapy, however, played such an important role in the management of casualties with abdominal injuries that it must be discussed in some detail here. Furthermore, the important causes of shock deserve careful consideration in relation to therapy and therapeutic failure in these injuries.

The background of this discussion is a series of 957 casualties selected for this purpose from the whole series of 3,154 casualties with abdominal wounds who were treated by surgeons of the 2d Auxiliary Surgical Group during 1944 and 1945. Selection was on two grounds: (1) That all the injuries included perforations of hollow viscera and therefore carried the threat of fulminating peritonitis, and (2) that in all cases data relative to shock therapy were complete. The figures for replacement therapy, as well as the case fatality rates, must be interpreted with the reservation that the selected series perhaps contains an undue proportion of poor-risk cases, the explanation being that the data were more likely to be complete in such cases than in cases in which the surgical risk was better.

¹ The term "shock" throughout this discussion should be understood as synonymous with the term "traumatic shock." An attempt to distinguish between traumatic and hemorrhagic shock would serve no useful purpose.

² Medical Department, United States Army, Surgery in World War II. The Physiologic Effects of Wounds. Washington: U. S. Government Printing Office, 1952.

The initial care of casualties in World War II fell into three phases: (1) Preoperative resuscitation or the therapy of traumatic shock, (2) definitive surgery, and (3) postoperative care. Care could not be considered optimal unless these three phases were closely integrated to insure complete continuity of effort. The immediate aim of shock therapy was to restore the circulatory dynamics to a sufficient state of competence to permit a successful operation. If a fatal outcome from the deleterious effects of shock, continuing peritoneal contamination, and the establishment of widespread virulent infection was to be prevented, it was essential that both resuscitation therapy and surgery be accomplished with as little delay as possible. Moreover, replacement therapy frequently had to be continued during operation and throughout the first days after operation.

The medical officer responsible for triage and shock therapy played a unique role in the care of battle casualties. His chief asset was the ability to judge the gravity of the situation. His initial examination established the status of the patient with respect to the extent of injury and the severity of shock and permitted tentative decisions as to appropriate replacement therapy and the response to be anticipated from it. Thereafter he carefully followed the patient's progress during transfusion therapy so as to recognize promptly any failure of response or actual deterioration. Sound judgment was especially needed in reaching a decision as to the optimal time to operate upon a patient with continuing intra-abdominal hemorrhage. Often the shock officer had to decide who, among a number of wounded men, was in most urgent need of immediate surgery, as well as whose chance of survival would be least compromised by delay.

Intelligent triage during the period of resuscitation was difficult to achieve because it depended upon awareness, experience, and judgment which were not easily acquired. Nevertheless, skill in this, as in surgical technique, was an extremely important factor in the successful treatment of the seriously wounded.

The objective of treatment was thus a continuity of therapeutic endeavor which afforded optimum coordination of replacement and surgical therapy and which recognized the fundamental importance of operation in the resuscitation of the severely wounded. The operation was of special importance in resuscitation when, because of continuing intra-abdominal hemorrhage or early fulminating infection, transfusion therapy alone had failed to bring about sustained improvement. Obviously, more than blood replacement was required to correct these conditions. The only hope for a successful outcome—and frequently the hope was slight—lay in supplementing massive transfusion therapy by prompt and skilled surgery. The care of these casualties thus constituted a challenge to all those responsible for all phases of their management in forward hospitals.

CLASSIFICATION OF SHOCK

The classification of shock into categories for statistical purposes is never entirely satisfactory, since the objectivity of different observers naturally varies considerably and their interpretations vary accordingly. For purposes of comparison and reference, however, four degrees of shock (table 18) were recognized in the 957 instances of traumatic perforation of the gastrointestinal tract upon which this discussion is based: (1) No shock, or incipient shock, in which the lower level of the systolic blood pressure was 101 mm. Hg; (2) moderate shock, in which the systolic blood pressure was 71 to 100 mm. Hg; (3) severe shock, in which the systolic blood pressure was 41 to 70 mm. Hg; and (4) profound or preterminal shock, in which the systolic blood pressure ranged downward from 40 mm. Hg to 0. More than half of the 957 patients in this series (table 18) exhibited degrees of shock ranging from moderate through preterminal, and more than a quarter exhibited severe or profound shock.

TABLE 18.—Administration of replacement therapy in relation to degree of shock in 957 traumatic perforations of the gastrointestinal tract

Degree of shock	Cases	Proportion	Deaths	Case fatality rate	Time-lag (average)	Replacement therapy (average)					
						Preoperative		During operation		Total	
						Plasma	Blood	Plasma	Blood	Plasma	Blood
		Percent			Hours	cc.	cc.	cc.	cc.	cc.	cc.
None or incipient (101 to 120 mm. Hg).....	446	46.6	81	18.2	10.4	492	619	178	962	670	1,581
Moderate (71 to 100 mm. Hg).....	250	26.1	95	38.0	11.6	602	873	261	1,063	863	1,936
Severe (41 to 70 mm. Hg).....	121	12.7	61	50.4	10.7	687	1,271	311	1,278	998	2,549
Profound (0 to 40 mm. Hg).....	140	14.6	93	66.4	10.8	713	1,745	311	1,617	1,024	3,362
Total	957	100.0	330	34.5	10.7						

The chief shortcoming of a classification based on the level of the blood pressure lies in the fact that the blood pressure was often maintained at relatively normal levels for a considerable period of time following injury. As a result, the soldier's condition might seem better than it really was (cases 1 through 4).³ Oligemia and reduction of the peripheral blood flow in the patients classified as not in shock or in incipient shock were likely to be disproportionately greater than the level of the systolic pressure would indicate. This was not true, however, of the other categories. All the experience in forward hospitals indicated that when once the blood pressure had fallen below normal levels, certain therapeutic and prognostic implications were inherent in the initial reading.

³ For the protocols on these cases and the other cases referred to in this chapter, see a Clinicopathologic Study of Abdominal Wounds, at the end of the chapter.

TIMELAG AND CHARACTER OF WOUND

The average timelag between wounding and operation in these 957 casualties with traumatic perforations of the gastrointestinal tract varied from 10.4 to 11.6 hours (table 18). Aside from the fact that it was slightly less in patients with no shock and with incipient shock than in those in other categories, there was no correlation between timelag and the severity of shock as indicated by the level of the blood pressure. Obviously, in wounds of equal severity, the total amount of blood lost and the severity of shock would increase with the passage of time (case 4). A patient admitted 10 hours after injury, for example, might exhibit signs of severe shock, whereas if he had been admitted 4 hours after injury, only moderately severe shock might have been observed.

The correlation between the degree of shock and the severity of the wound is borne out by an analysis of the cases in this series. Not only did the patients in the deepest shock consistently exhibit more severe injuries than those whose blood pressure approached normal, but multiple visceral injuries were also more common in the categories of severe shock (cases 5 through 8). The high case fatality rate in patients with combined gluteal and abdominal wounds was almost certainly related to the frequency in such injuries of massive hemorrhage from the iliac and femoral vessels (cases 1, 5, 6, and 9). Lacerations of the spleen and major vascular injuries furnished other illustrations of the relation of vascular injuries to the degree of shock. Of the 140 patients with gastrointestinal perforations in the category of profound or preterminal shock, 43 (30.7 percent) had associated injuries of this sort, as did 21 of the 121 patients (17.4 percent) in the category of severe shock. In contrast, this type of injury was present in only 39 of the 250 patients (15.6 percent) in moderate shock, and in only 37 of the 446 patients (8.3 percent) in incipient shock or not in shock.

ROLE OF HEMORRHAGE AND OTHER FLUID LOSSES IN PATHOGENESIS OF SHOCK

Massive hemorrhage was frequently present in injuries of the abdomen, as the result of disruption of a major vessel or a laceration of the spleen or the liver. Even in the absence of such major injuries, widespread damage of smaller vessels could account for a considerable blood loss. Blood loss was undoubtedly the most important factor in the production of traumatic shock in patients with abdominal injuries. It was also chiefly responsible for the depression of the hematocrit frequently observed in battle casualties. On the other hand, it had to be remembered, in the appraisal of severe shock, that the administration of plasma also tended to reduce the hematocrit and the oxygen-carrying capacity of a given volume of blood. If an excessive amount of plasma had been given after hemorrhage, the total volume of the circulating blood might be only moderately reduced; yet a marked anemia might be present, with a hematocrit reading of only 15 to 18 percent. This observation, incidentally, furnishes additional proof of the superiority of whole blood over reconstituted plasma in the resuscitation of battle casualties (p. 22).

In addition to hemorrhage, the loss of plasma or of plasma components into the traumatized or contaminated area of the abdomen contributed materially to the production of shock. This loss occurred as the result of transudation or exudation of fluid from inflamed peritoneal surfaces and into visceral tissues under the influence of mechanical and chemical trauma and beginning infection. While the precise importance of fluid loss from this source has been disputed, certain observations made by the surgeons of the 2d Auxiliary Surgical Group caused them to be inclined to regard it as significant. An extremely high case fatality rate was observed when the pleura was widely contaminated by gastric or intestinal contents, and the shock present in this type of case was apt to be especially severe (cases 4 and 10). Similarly, diffuse peritoneal contamination consistently increased the severity of the circulatory collapse associated with evisceration of the intestines (case 11). When, on the other hand, evisceration occurred without appreciable peritoneal soiling, shock was often surprisingly mild, and the response to replacement therapy was more favorable than in the presence of diffuse contamination of the peritoneum.

Changes in the splanchnic capillary bed produced by irritation and infection also appeared to be of some importance in reducing the effective circulating blood volume, though there was no agreement concerning the quantitative influence exerted by these alterations. Mann⁴ had noted in 1915 that mechanical trauma to the bowel was associated with an increased capacity of the splanchnic vascular bed. Similar observations were made by the surgeons of the 2d Auxiliary Surgical Group who found that, in patients with perforations of the gastrointestinal tract, a considerable volume of blood was likely to be pooled in dilated and engorged venules and capillaries and that the accumulation was increased when the bowel was manipulated at operation.

Another source of fluid loss was dehydration, which existed in some degree in all patients with gastrointestinal perforations, whether or not vomiting had occurred. Because of paralytic ileus, which was a natural consequence of peritoneal contamination or infection, small-bowel contents did not reach the colon, and the normal reabsorption of water did not occur.

Although the loss of plasma or its components into the contaminated peritoneal cavity resulted in a rise in the hematocrit of the circulating blood, hemorrhage, which was an almost universal sequela of penetrating wounds of the abdomen, ultimately had the opposite effect. The hemodilution which follows hemorrhage would seem to account for the fact that even in severe shock associated with widespread soiling of the peritoneum, hemoconcentration was seldom observed and was, in itself, a factor of negligible significance in the pathogenesis of shock in battle injuries.

Furthermore, a patient who showed clinical evidence of severe shock might occasionally present no significant decrease in the hematocrit level, and there was frequently little apparent correlation between the hematocrit reading and the severity of peripheral circulatory failure. On the other hand, con-

⁴ Mann, F. C.: Shock and Haemorrhage: An Experimental Study. *Surg., Gynec. & Obst.* 21: 430-441, October 1915.

siderable hemodilution was often found in association with severe shock. These low hematocrit levels, as already mentioned, were usually observed in cases in which the initial blood loss had been severe and in which large amounts of plasma had been used to prevent death within a short time after injury. The subsequent management of these patients was always difficult, a fact that was not always readily apparent at the time of the initial examination.

The maintenance of a normal or slightly elevated hematocrit level in a patient with a penetrating wound of the abdomen did furnish some evidence that the effects of peritoneal contamination had equaled or exceeded the effects of hemorrhage. So many factors, however, influenced the hematocrit in wounds of the abdomen that its usefulness as a means of quantitative assessment of the loss of blood or of plasma components from the circulation was quite limited.

REPLACEMENT THERAPY

Aside from any theoretic considerations, increasing experience led the surgeons of the 2d Auxiliary Surgical Group to emphasize the important role of local loss of fluid, particularly blood, in the initiation of the traumatic shock which followed penetrating wounds of the abdomen. Undeniable support for their position was furnished by the proved efficacy of plasma and whole-blood replacement in the resuscitation of these severely wounded men.

Replacement therapy was frequently begun in the battalion aid station with the administration of reconstituted plasma. Whenever severe shock was apparent soon after injury, plasma was usually given, occasionally in excessive amounts. Plasma received under these circumstances is included in the calculation of the average figures for replacement therapy in this series (fig. 25; table 18).

The total amounts of blood and plasma used for resuscitation were proportionate to the severity of the shock exhibited by the casualties. Furthermore, the volume required in each category of shock agreed fairly well with the estimate of blood loss made by the Board for the Study of the Severely Wounded.⁵ These facts lend support to the contention that the level of the blood pressure is, in spite of its shortcomings, an important criterion in the evaluation of the degree of shock and the extent of blood loss in severely wounded casualties.

Although application of average data to individual casualties would naturally be expected to reveal discrepancies, nevertheless the values calculated as average for this relatively large series may be taken as a general guide to the requirements which had to be met in preoperative resuscitation. Patients suffering from severe shock often had to be given extremely large quantities of plasma and blood. The administration of 5,000 to 6,000 cc. was not unusual. Uncontrollable hemorrhage during operation also called for the

⁵ Medical Department, United States Army, Surgery in World War II. The Physiologic Effects of Wounds. Washington: U. S. Government Printing Office, 1952, pp. 21-74.

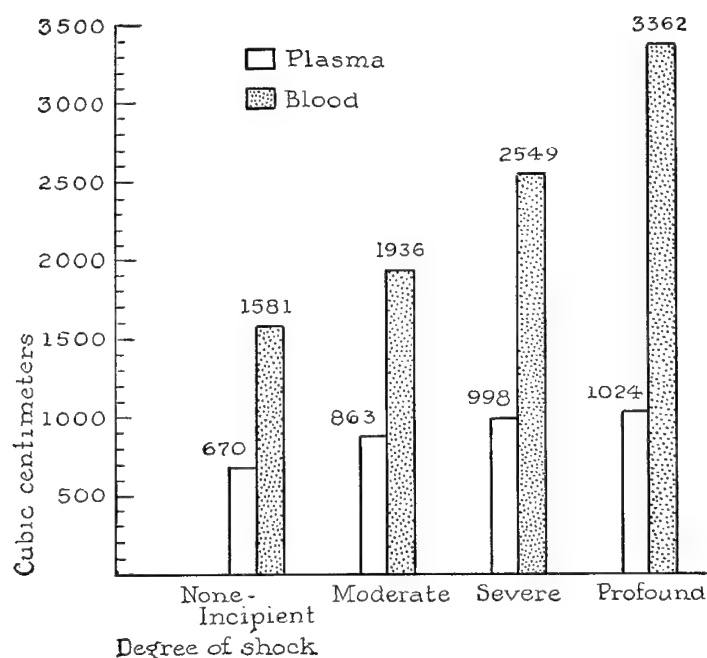


FIGURE 25.—Average replacement therapy (whole blood and plasma) in relation to degree of shock in 957 abdominal injuries with perforation of gastrointestinal tract.

use of very large amounts of fluid. One patient in this series, for example, received a total of 8,250 cc. (1,750 cc. of plasma, 6,500 cc. of whole blood), chiefly because intra-abdominal bleeding could not be effectively controlled during the early phase of the operation.

Adequate replacement therapy was not available in World War I, and surgeons quickly recognized the futility of attempting operation in the presence of severe traumatic shock. Had the same lack of replacement therapy prevailed in World War II, the severity of shock would have precluded operation in many of the 261 patients in this series whose systolic blood pressures were 70 mm. Hg or less (table 18). Operation was attempted in the field hospital in every instance, however, after adequate replacement therapy, and 107 (41 percent) survived to be evacuated to the rear, after the usual period of convalescence.

Accurate data are not available concerning deaths before operation in patients in severe shock after perforation of the gastrointestinal tract. Presumably the number was small. During a 4-month period in 1944-45, a single shock team lost only 6 patients (2.1 percent) of the 285 it was attempting to prepare for operation.

During World War I, Maj. J. W. Vaughan, MC, consulting surgeon, 32d Division, recorded that of 256 patients sent from the triage to an operating station for seriously wounded, 41 died in spite of attempts to combat shock

by various methods, leaving only 215 who received operative treatment.⁶ In marked contrast, under similar circumstances in a field hospital platoon in 1943, there were no preoperative deaths among 297 consecutive patients admitted for surgery.

The saving of life in World War II among casualties in severe and profound shock was largely attributable to liberal, and frequently massive, transfusions. In numerous instances operation would have been impossible without such therapy. The improvement which followed prompt and intensive replacement therapy was often striking, particularly among patients who had suffered very severe shock of relatively short duration. Improvement was not observed uniformly in this category, it is true, but it occurred with sufficient frequency to emphasize the therapeutic potentialities of liberal replacement therapy in the resuscitation of severely wounded men.

Failures of Replacement Therapy

The fact that significant or sustained improvement did not invariably occur after replacement therapy suggested that, in spite of the importance of the fluid loss in the pathogenesis of shock and the unique role of replacement therapy in its management, other factors, which were probably not completely amenable to this type of therapy, had to be taken into account.

One of the most important of these additional factors was massive peritoneal contamination, with early fulminating peritonitis, the deleterious effects of which were often augmented by severe hemorrhage, a prolonged timelag, or both.

The case fatality rate in the various categories of shock in this series was directly related to the degree of shock (table 18). The steadily ascending rate emphasized the increasing gravity of the prognosis as the degree of shock increased. About three-quarters of the deaths in the 3,154 cases in the total series occurred by the end of the second postoperative day. Casualties who died within this period often pursued a relentlessly downhill course characterized by persistent or recurrent shock. It was soon learned that failure of the patient to manifest sustained benefit from adequate resuscitative measures, particularly when replacement therapy had been liberal and intensive, was clear evidence that the prognosis was grave (cases 8, 9, and 12).

The course of such a patient was characteristic. When he was received at the field hospital he was in shock, which often was severe. The blood pressure was extremely low. The pulse was rapid and of poor volume. The extremities were cold. The skin was pale, and if the degree of shock was profound there was often more or less purple-red mottling or cyanosis. Venous filling was apt to be poor, even after a tourniquet had been applied. The rectal temperature was seldom above 100° F. and was frequently subnormal. The patient was aware of his extreme weakness, complained little if at all, and wanted

⁶ The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1, pp. 109-110.

to be left undisturbed. The sensorium was likely to be clouded, but in the absence of acute morphinism true coma was not common except as a terminal manifestation. Appraisal of the history often suggested that the timelag, although perhaps not intolerable in itself, had become intolerable because of the extent and character of the wound. Considerable transient improvement might be attained by liberal transfusion therapy, but the clinical response was likely to be incomplete or poorly sustained, and increasingly severe shock often supervened after operation. In fact, one of the most constant characteristics in this type of case was the tendency to recurrent shock.

The terminal decline as a rule occurred shortly after operation, but in many instances it was sufficiently delayed for widespread bacterial growth to occur. Death was usually attributable to shock or to shock and peritonitis, but the peritonitis, it must be emphasized, differed from the type of purulent peritonitis familiar in civilian practice (p. 198). It was characterized by massive contamination of the peritoneum and by the gross pathologic changes observed during the early stages of bacterial growth. In addition, the circulatory and metabolic changes associated with severe traumatic shock, as well as the overwhelming nature of the peritoneal infection, appeared to be capable of inhibiting to an appreciable degree the local leukocytic response. Autopsy revealed edema and discoloration of the intestine, opacity and dullness of the serosal surfaces, a moderate amount of turbid, serosanguineous exudate, and relatively little fibrin (cases 7, 8, 10, and 11). A purulent exudate of significant amount was not usually seen, probably because of the brief duration of the inflammatory process.

The peritoneal reaction which was the result of early massive soiling thus differed materially from the usual bacterial peritonitis of 4 to 6 days' duration. Early in the war, the deleterious local effects of such soiling were not always appreciated because the surgeon's judgment was based on knowledge limited to the classical variety of peritonitis.

Preexisting traumatic shock was undoubtedly the explanation of the promptness and frequency with which death occurred after wounding in this type of peritonitis. When massive peritoneal contamination was further complicated by continuing intra-abdominal hemorrhage, successful resuscitation and surgery were often impossible.

In some cases, in spite of massive transfusion therapy, careful surgery, chemotherapy, oxygen therapy and all other available measures, the fatal outcome was merely delayed for a day or two. Its apparent inevitability, in spite of what seemed to be adequate replacement therapy, introduced the question of the possible role of toxic factors in the production of so-called irreversible shock. The toxic theory is particularly interesting because of the massive peritoneal contamination and the associated circulatory failure present in many of these severely wounded men. The analogy to anaerobic myositis was suggestive, especially because in a few instances pure cultures of *Clostridium welchii* were obtained from the peritoneal cavity. Similar infections of the pleural cavity were occasionally observed (case 13). These isolated observa-

tions, however, cannot be construed as valid evidence that the same factors were responsible for severe shock in the presence of peritoneal contamination. The role of toxicity cannot be denied on the basis of the evidence at hand, but a toxic factor, other than infection per se, remains to be isolated and established.

It should be realized that the exigencies of warfare often precluded the accumulation of data which would fully explain the apparent failures of replacement therapy in the management of shock. In the absence of these data, unwarranted conclusions were frequently drawn relative to the effect of what were termed toxic factors. When comparatively complete clinical and post mortem data were critically analyzed, these conclusions usually could not be substantiated. The protocols found at the end of this chapter (cases 1 to 4, inclusive; 9; 10; 14; and 15) disclose various findings which, regardless of their relationship to shock, limited the chance of survival of the seriously wounded. The investigations of the Board for the Study of the Severely Wounded⁷ afforded no evidence of the existence of toxic agents and led the investigators to suggest that the term "irreversible shock" should be abandoned because of its implications in this respect.

Excessive prolongation of the period of peripheral circulatory failure was apparently the most important reason for failure of liberal replacement therapy to accomplish resuscitation in some cases. The importance of the duration of shock cannot be arrived at by a simple analysis of statistical data (table 18). There was no significant correlation, as already pointed out, between the severity of shock and the duration of injury before operation. Moreover, it was frequently impossible to determine the exact duration of the observed state of shock from the field medical record.

It was readily apparent, however, that the more severe the peripheral circulatory failure, the more rapidly did a state of profound or so-called irreversible shock ensue. A relatively short period of delay in resuscitation might prove fatal to a patient in severe shock, although it could easily be tolerated by a patient in moderate shock. Traumatic shock, satisfactorily alleviated by the prompt transfusion of 1,500 to 2,000 cc. of whole blood, could constitute irreversible shock in the absence of such therapy. It is a rather general custom to label shock as irreversible when the therapy at hand has proved to be unsuccessful, but this is a vague characterization defined by therapeutic trial, not by exact knowledge of the fundamental pathologic physiology.

All the World War II experience indicated that peripheral circulatory failure is followed, within a variable period of time (the variation depending upon its severity), by alterations in general cellular metabolism which cannot be corrected by transfusion therapy alone. These changes were thought to depend upon the interruption of the supply of oxygen and other nutrients to large groups of cells, as, for example, those of the liver and kidney, rather than upon changes in the capillary endothelium. Shock therapy was effective only

⁷ See footnote 5, p. 124.

insofar as it restored adequate circulatory dynamics and alleviated tissue anoxia. Changes in cellular metabolism could thus be prevented or arrested, but they could not be completely reversed. In this respect, replacement therapy was always prophylactic.

If the metabolic changes associated with severe shock were thoroughly understood, the knowledge might serve to resolve the enigma of so-called irreversible shock without invoking factors other than fluid loss in its pathogenesis. Unfortunately, no simple methods were available during World War II—nor are they available now—by which the clinician could determine accurately the onset of irreversible cellular changes during the course of traumatic shock. The only solution of the problem was, therefore, to treat existing circulatory failure as promptly and as vigorously as possible.

THE TOTAL PICTURE OF SHOCK IN WORLD WAR II

The experience of the 2d Auxiliary Surgical Group with casualties in shock and in need of resuscitation following abdominal wounds apparently paralleled the total war experience. Local fluid loss undoubtedly was the most important factor in the initiation of traumatic shock. The most efficacious means of resuscitation was prompt and adequate replacement therapy, in which whole blood was the most important component. The nature of battle wounds of the abdomen demanded that prompt and expert surgery constitute an integral part of resuscitative therapy, in order to arrest hemorrhage and peritoneal contamination with the least possible delay. Many factors, not all of which were completely understood, augmented and perpetuated shock. One, which was extremely important, was massive contamination of body cavities. The circulatory disturbances of severe shock promptly led to bodily changes which could not be completely reversed by replacement therapy. Delay in initiating such therapy, as well as improper utilization of available measures, whether as the result of military exigencies or for other reasons, resulted in failures of resuscitation.

Many abdominal injuries were lethal, at least in relation to methods of resuscitation and surgery then at hand. They remained, at the end of the war, as a challenge for the future. It is in the resuscitation of gravely wounded men that the therapy of traumatic shock will meet its most severe test. Advances will depend upon a more fundamental knowledge concerning the relationship of massive peritoneal contamination to traumatic shock and death, as well as upon a more thorough understanding of the cellular derangements produced by severe shock. The failures in replacement therapy which occurred in World War II point to the need for further study of the problem but must not be interpreted to permit the neglect of available measures of resuscitation in the management of severely wounded men with abdominal injuries.

A CLINICOPATHOLOGIC STUDY OF ABDOMINAL WOUNDS ASSOCIATED WITH SHOCK

Introductory Note

In March 1944, the author of this study (Maj. Beverly T. Towery) had the good fortune to assume the direction of Shock Team No. 6, 2d Auxiliary Surgical Group, which was then engaged in the resuscitation of nontransportable casualties in the field hospitals of the Fifth United States Army, Mediterranean Theater of Operations. As explained elsewhere, the evacuation of gravely wounded casualties was always specifically interrupted in a forward medical echelon for the treatment of shock, followed by surgical intervention, after which the patient was retained in the field hospital for a period of convalescence.

At this time, almost no post mortem examinations were being carried out upon the fatal cases in this group of patients, although the high incidence of severe shock and the resulting deaths among these "casualties of immediate urgency" provided a remarkable opportunity for the study of the clinical as well as of the morphologic characteristics of wound shock. The tissues and clinical protocols which the microscopists received were often too inadequate to permit an intelligent interpretation of the findings. Conversely, reports of microscopic diagnoses usually failed to find their way back to the prosecutors.

With the enthusiastic encouragement of the late Lt. Col. Tracy B. Mallory, MC, a systematic program was set up for the clinical and post mortem study of patients who died in field hospitals, as follows:

1. The author, with only one or two exceptions, performed the post mortem examinations.
2. He was responsible for providing the microscopist with a record of the gross anatomic findings.
3. With this report, he also included provisional diagnoses and a brief summary of the case, based upon the autopsy findings and the clinical data available at the time of the post mortem examination.
4. The microscopists provided histologic descriptions of the tissues, added microscopic diagnoses, and frequently wrote brief comments upon their observations.
5. The original observations made by the prosecutor were retained in the protocols, and the provisional diagnoses were not amended to conform to the subsequent reports of microscopic findings. Such inconsistencies as might have arisen were discussed and rectified in the final summarizing statements attached to the end of each protocol.

During the 13-month period in which this program was continued, it was possible to accumulate relatively complete clinical and post mortem data upon 47 men who had been wounded under varying circumstances of terrain, climate, and tactical situation in Italy, France, and Germany. Thirty of these casualties (64 percent) had sustained wounds of the abdomen. The 15 protocols which follow have been selected from this group of cases, in an attempt to define

clearly the magnitude of the problem of shock among patients with abdominal injuries. It is believed that these records constitute representative source material.

The author was personally responsible for part or all of the resuscitation in most of the cases in the total series. As collator, however, he has drawn freely upon the clinical observations of numerous colleagues in respect to replacement therapy, anesthesia, surgical management, and postoperative care.

This study clearly showed that hemorrhage and peritoneal contamination were the most important determinants of the outcome of intra-abdominal trauma. Regardless of the ultimate detrimental effects of peritoneal contamination, the early onset of severe shock was almost invariably due to brisk hemorrhage. Widespread peritonitis unquestionably increased the likelihood of a fatal outcome, though, aside from the attendant local loss of fluid, the mechanism of the deleterious effects of this complication remained unexplained in this study. A morphologic evaluation of these phenomena proved to be a difficult undertaking and one which, on theoretical grounds, was not particularly rewarding. From a practical standpoint, however, the demonstration of a microscopic lesion, such as diffuse pulmonary fat embolism, sometimes provided crucial data in a fatality which otherwise might have remained obscure.

Resuscitation by means of vigorous replacement therapy removed, at least in part, the immediate risks of shock but seemed to accentuate certain microscopic changes contingent upon partial or complete recovery from it. Hemoglobinuric nephropathy was perhaps the most striking of these lesions, and the importance of post traumatic renal failure will be readily apparent on a perusal of these records. It is ironical that the development of this particular lesion seemed to depend upon a measure of success in resuscitation.

One of the major aims of this study was to obtain evidence concerning the fundamental pathogenesis of irreversible shock. The results were illuminating. In effect, it was evident that a careful post mortem examination very often revealed findings which provided some other logical explanation for the fatality. Among these findings were unrecognized perforations of the gastrointestinal tract, the autotransfusion of contaminated blood, unsuspected infection, pulmonary edema, and cerebral emboli. On the basis of the experience obtained in this investigation, one would therefore be inclined to minimize the importance of shock which does not have a reasonable explanation in terms of hemorrhage, exudation, and infection.

Protocols⁸

Case 1

CLINICAL DATA

This patient received a bullet wound of the left hip on 2 June 1944, at 1000 hours. When he reached a field hospital at about 1600 hours, after having

⁸ The author gratefully acknowledges the generous assistance in this study of the various pathologists whose microscopic studies (sometimes identified by initials) appear in the protocols. He is particularly indebted to the late Lt. Col. Tracy B. Mallory, MC, and to 1st Lt. Leslie S. Jolliffe, MC, and Capt. Joseph G. Rothenberg, MC. First Lt. Kathryn T. Driscoll, ANC, provided invaluable clerical assistance.

received 250 cc. of plasma, his blood pressure was 110/60 mm. Hg. He did not appear to be in shock, but examination of the abdomen revealed generalized rigidity. He was given 500 cc. of plasma and 500 cc. of blood before operation, and his condition seemed relatively good. His blood belonged to group A.

At operation, much blood was found in the peritoneal cavity. The missile had perforated the abdomen by way of the left buttock. When exploration was attempted, profuse hemorrhage occurred from the left iliac vessels, and the aorta and inferior vena cava were temporarily ligated with tape. After a great deal of difficulty, it was possible to ligate the left external iliac vein, and the internal iliac vein and artery.

The patient's condition was extremely poor during this procedure, and he was given 4,500 cc. of group O blood in an attempt to replace the blood loss. Extensive exploration of the abdomen was not carried out, but there was no evidence of perforation of the intestine or of peritonitis. At the end of the procedure, which lasted approximately 7 hours, the blood pressure was 100/40 mm. Hg; it had risen considerably after bleeding had been controlled.

The right leg became moderately cyanotic after operation, and, on both the first and second postoperative days, right lumbar sympathetic blocks were performed with procaine. Some improvement was noted. On the second postoperative day, the temperature was 98.6° F., the pulse was 100, and the respiration was 24. When the patient was catheterized, only 60 cc. of dark-brown urine was obtained, although the fluid intake had been adequate. Its specific gravity was 1.025. The patient became somewhat confused and died at 2000 hours 4 June 1944, 58 hours after wounding.

AUTOPSY

Autopsy was performed 5 June 1944, 12 hours after death (Cori, Italy).

Gross observations.—The delay in performing the autopsy, without benefit of refrigeration, had produced marked changes in the body. The pericardial cavity contained 30 cc. of pink serous fluid, and 120 cc. of similar hemolyzed blood-stained fluid was present in each of the pleural cavities. The peritoneal cavity was not remarkable, except for generalized pink (hemoglobin) staining of the serous surfaces.

The lungs showed bilateral and symmetrical edema and deep purple-red discoloration, with considerable reduction in crepitus. No bronchial obstruction was present nor were any emboli present in the carefully dissected branches of the pulmonary artery.

Two perforations were observed in the retroperitoneal portion of the ascending colon. They were caused by passage of the bullet through this viscus about 8 cm. distal to the ileocecal valve. There was also extensive retroperitoneal hemorrhage in this region, with a rather scanty fibrinopurulent exudate.

The kidneys were swollen and moderately increased in size. The cut surface bulged above the edge of the capsule. The cortex was rather pale, but

its pallor was modified by hemoglobin staining of all the tissues. Hydroureter and renal-vascular occlusion were not present.

The finer detail of the pelvic vessels was greatly obscured by extensive suffusion of tissues by markedly hemolyzed blood.

Sections of muscle taken from the upper thigh on the left were not grossly remarkable except for moderate pallor.

Gross anatomic diagnosis.—(1) Penetrating gunshot wound of left buttock, with two perforations of retroperitoneal portion of ascending colon and early retroperitoneal abscess; lacerations of left common iliac vein, external iliac vein, and internal iliac artery and vein, all secondarily ligated; and (2) severe, exsanguinating hemorrhage, secondary to these lacerations.

Comment.—Death may be ascribed to shock, secondary to severe and prolonged hemorrhage. Since death occurred on the second postoperative day, the perforations of the colon may have had relatively little to do with the fatality. These perforations, however, served to contaminate the wound track with anaerobic organisms, and clinical manifestations would probably have supervened shortly, had the patient survived. How important this contamination was in causing death must remain conjectural. The oliguria present before death suggested a renal lesion, but in all probability the inadequate renal blood flow (hypotension) during the postoperative period was alone responsible for the decreased urinary output.

Microscopic observations.—Histologic examination of the kidney showed the lower nephron segments to be extensively plugged with pigmented casts. In the cortex, some tubules contained masses of intensely blue-staining granules and spherules suggesting calcareous material. These masses were not found in the pyramid. There were many bacilli in the interstitial tissues, and fixation was too poor to judge epithelial degeneration.

Examination of the bowel showed much of the mucosa to be necrotic. All layers of the wall were infiltrated with leukocytes, and the serous surface was covered by a thick fibrinopurulent membrane.

Comment.—The severe lower nephron nephrosis of the hemoglobinuric type is suggestive of a transfusion reaction. The story of the administration of 4,500 cc. of group O blood to a group A recipient within a period of a few hours is interesting and may have been the responsible factor. The clostridial infection was evidently only agonal and cannot be held responsible for the fatality. There was no massive necrosis of voluntary muscle which could have produced myohemoglobinuria. The calcareous masses in some of the tubules are assumed to represent past history; they could be remnants of a previous sulfonamide reaction. (T. B. M.)

SUMMARY

Death probably was due to a combination of factors in this case: (1) Severe shock during a prolonged operation; (2) perforation of the colon with contamination of the retroperitoneal tissues; and (3) renal failure, with consequent

pulmonary edema. Of these factors, the first seems to be of greatest importance, since death occurred within a relatively short time after operation. Uremia per se was probably not of primary importance in causing death; under the conditions at hand it is extremely difficult to assess the importance of infection in this case.

Case 2

CLINICAL DATA

This patient received shell-fragment wounds of the left thigh and right costal margin 19 March 1945 at 0230 hours. A tourniquet was applied to the left leg at 0300 hours. When the patient reached a field hospital at 0630 hours, after having received 500 cc. of plasma, the blood pressure was 110/70 mm. Hg, and the pulse was 80. Before operation, he was given 600 cc. of plasma and 500 cc. of whole blood. His blood belonged to group AB.

Anesthesia was begun at 1105 hours 19 March. Laparotomy revealed a laceration of the right lobe of the liver and severe destruction of a 10-cm. portion of the transverse colon. A spur colostomy was made through the right upper quadrant, and drains from the hepatic laceration were brought out through the wound at the right costal margin. The operation required 3½ hours, and during it the patient received 2,000 cc. of whole blood.

In addition to his abdominal wound, this patient had a fracture of the lower third of the left femur, with severe comminution and posterior angulation of the distal fragment.

The day after operation, the patient was semistuporous. The blood pressure was 84/50 mm. Hg and the pulse 140. He received 500 cc. of plasma. Medium rales were heard in both lungs. Moderate cyanosis was relieved by the administration of oxygen. There was profuse drainage of bile-stained fluid from the drains at the right costal margin. During the first 12 hours after operation, the patient excreted 275 cc. of urine. His respirations were quite shallow, and he coughed only occasionally and ineffectually. He died at 1630 hours on the second postoperative day, 62 hours after wounding.

AUTOPSY

Autopsy was performed 4 hours after death (St. Avold, France).

Gross observations.—The abdomen was moderately distended, in spite of the presence of several drains. The peritoneal cavity contained about 300 cc. of blood-tinged, purulent fluid, which was present chiefly above and posterior to the colostomy spur; a moderate amount of yellow-gray purulent exudate was also found in this area. There was considerable dilatation of the stomach and of the upper bowel down to the point at which the small bowel was partially obstructed as it lay posteriorly and lateral to the proximal segment of the colostomy. Distal to this point, the bowel was not distended, though the loops

were lightly bound together by fibrinopurulent exudate. There was no leakage into the peritoneal cavity from the colostomy, the transverse spur of which appeared to be under slight tension.

The right auricle was considerably distended by blood. The tricuspid valve appeared slightly dilated. There were petechial hemorrhages over the surface of the posterior aspect of the heart, particularly along the coronary sulcus. On section, the myocardium appeared paler than normal.

There were severe partial atelectasis of both lungs; the aeration of all lobes except the left upper lobe was moderately to markedly decreased. There was well-established nodular consolidation of the entire right lower lobe, the hilar portion of the right middle lobe, and the posterior portion of the right upper lobe. Near the hilus of the right lower lobe there appeared to be beginning abscess formation.

The spleen was of usual size and was covered by a thin layer of fibrinopurulent exudate. On section, it was purple red and moderately firm, but the pulp scraped away readily.

There was a small laceration of the lateral margin of the right lobe of the liver, but no appreciable collection of bile was present within the peritoneal cavity. In the dome of the right lobe was a large, irregular area of yellow mottling. There was no evidence of suppuration in the tissue adjacent to the laceration.

The kidneys were somewhat smaller than normal, and the capsular surfaces were smooth and pale pink, with small irregular patterns of vascular congestion. The cut surface was not remarkable. The adrenals were normal.

Gross anatomic diagnosis.—(1) Perforating shell-fragment wound of abdomen, via upper right flank, with exit just to right of umbilicus, with moderately severe laceration of right lobe of liver, and severe perforation and laceration of right transverse colon, with spur colostomy; (2) acute, moderately severe, fibrinopurulent peritonitis, secondary to perforation of transverse colon; (3) severe pulmonary atelectasis, involving all lobes, with early acute bronchopneumonia of right lung and left upper lobe, and possible abscess of right lower lobe; dilatation of right auricle and subepicardial petechial hemorrhages probably due to atelectasis and asphyxia (possibly terminal); (4) perforating shell-fragment wound of left lower thigh, with complete, compound, comminuted fracture of lower third of left femur and laceration of capsule of left knee joint and of suprapatellar bursa; and (5) lacerating shell-fragment wound of left chest wall near 12th rib.

Comment.—The immediate cause of death in this case appears to have been atelectasis and bronchopneumonia. The post mortem findings suggest that these complications began soon after operation. The semistuporous state and the diffuse peritonitis and distention of the stomach and upper small bowel were probably responsible for the poor respiratory exchange and ineffectual cough. In the presence of severe bone trauma, stupor and pulmonary rales suggest the possibility of fat embolism.

Microscopic observations.—In the alveoli of the lungs were large amounts of eosinophilic coagulum and varying degrees of polymorphonuclear infiltration into the coagulum. A second section revealed dissolution of the alveolar walls with extreme infiltration and accumulations of polymorphonuclear leukocytes. In the central portions of these accumulations were bacterial groups and necrotic debris. Some alveolar walls which were still present appeared necrotic. Thrombi were seen in the vessels in these areas. On the pleural surface was a thin, fibrinoid material with enmeshed polymorphonuclear leukocytes. Large amounts of eosinophilic coagulum were seen in alveoli along with polymorphonuclear leukocytes.

In the section studied from the liver, small vacuoles were seen throughout the parenchyma. About the central vein, which was slightly dilated, slight sinusoidal congestion was observed.

The sinusoids of the spleen were dilated and congested.

The tubular cytoplasm of the kidney was granular. Many of the nuclei were indistinct or absent. The glomeruli were not remarkable.

Vacuolation of cortical cells was most noticeable in the zona glomerulosa of the adrenal glands.

Microscopic diagnosis.—(1) Lobular pneumonia with abscess formation, (2) moderate fibrinopurulent pleuritis, (3) severe acute purulent peritonitis, (4) edema of small intestine, and (5) traumatic necrosis of liver.

SUMMARY

This case is an instance of severe abdominal injury. After a relatively short delay, the patient reached the field hospital in surprisingly good condition. In spite of the many favorable circumstances, however, he died of plmonary atelectasis and bronchopneumonia on the second postoperative day. Peritonitis was probably also a contributory factor in the fatality. It is unfortunate that microscopic studies of the lung were not sufficient to exclude pulmonary fat embolism.

Case 3

CLINICAL DATA

This patient received a bullet wound of the left abdomen 18 April 1945 at 1800 hours. When he was admitted to a field hospital at 2215 hours, his blood pressure was 130/80 mm. Hg. He received 500 cc. of group A (his blood group) blood before operation. His condition during the preoperative period was relatively good.

As the peritoneal cavity was being opened, the blood pressure fell abruptly to 0/0 mm. Hg. The systolic pressure rose to 90 mm. Hg when 1,500 cc. of whole blood were given rapidly. As abdominal exploration was continued, a large quantity of blood was found in the peritoneal cavity. There was a severe laceration of the proximal jejunum; a small segment was resected and an end-to-

end anastomosis was performed. A lacerated segment of the colon was exteriorized through a stab wound in the left upper abdomen. Operation was completed 19 April at 0220 hours.

Immediately after operation, the systolic blood pressure was 170 mm. Hg, which was attributed to a mild transfusion reaction during the operation. The blood pressure then progressively declined; it was 100/66 mm. Hg at 0830 hours 19 April and only 22/0 mm. Hg at 1200 hours. At this time, the patient appeared moribund. He had vomited large quantities of blood, and it was thought that the fall in blood pressure was caused by bleeding in the upper gastrointestinal tract.

In an attempt to control this bleeding, a second operation was undertaken at 1400 hours 19 April. At this operation, no blood was found in the peritoneal cavity. The original jejunal anastomosis was examined through an opening made in the bowel just distal to it. At this time, although he had had 3,000 cc. of blood just before the operation and during its course, the patient was in severe shock. No point of bleeding could be found along the line of resection. The anastomosis was, nevertheless, reenforced by an additional row of through-and-through sutures, and the jejunotomy was closed. A gastrotomy was then performed, and a large volume of clotted blood was removed from the stomach. There was no evidence of gastric bleeding from the mucosal surface, which was examined as completely as possible through the incision.

After the second operation, the blood pressure was 80/0 mm. Hg. By 1830 hours, it had fallen to 20/0 mm. Hg, and it did not again exceed this level. The patient expired in profound shock at 2220 hours 19 April 1945, 28 hours after wounding.

During his brief hospitalization, this patient received 5,500 cc. of whole blood, all group A and all carefully crossmatched with his blood.

AUTOPSY

Autopsy was performed 13 hours after death (Poxdorf, Germany).

Gross observations.—The body was not remarkable except for considerable dependent lividity.

The lungs showed only post mortem hypostasis.

The abdominal cavity was not remarkable except for the thin, opaque, fibrinous exudate which covered several loops of small bowel. This portion of the bowel was not distended, and there was no appreciable collection of purulent exudate.

The spleen was moderately enlarged and rather soft and appeared somewhat less congested than is usual after massive transfusion therapy.

The gastrotomy, jejunotomy, and jejunal anastomosis 8 cm. distal to the ligament of Treitz were all snugly sutured, and there was no evidence of leakage of bowel contents. When the gastrointestinal tract was opened, about 300 cc. of old blood were found in the stomach, and a small amount of similar blood was also found in the loop of jejunum at the site of anastomosis. The duo-

denum, which was free of blood, was deeply bile stained. In an attempt to locate a possible source of bleeding, the mesenteric vessels leading to the jejunojejunostomy were cannulated and infused with water, but no vascular leak was disclosed. Since no blood was present distal to the jejunostomy, the upper gastrointestinal tract was examined minutely. No source of hemorrhage was present. A small, shallow excoriation of the distal esophagus and another in the first portion of the duodenum showed no evidence of tissue reaction, and no vessels were exposed. No varices were present in the lower esophagus.

The kidneys were somewhat smaller than usual but were not remarkable on section. The left kidney and adrenal were partly surrounded by the blood in the retroperitoneal area.

Gross anatomic diagnosis.—(1) Penetrating bullet wound of abdomen with severe laceration of proximal jejunum, secondary resection and jejunostomy, jejunotomy; perforation of transverse colon, colostomy; and (2) exsanguinating postoperative hemorrhage from upper jejunum secondary to lacerating wound of jejunum, with the operations described.

Comment.—A very careful examination of the upper gastrointestinal tract failed to reveal any source of hemorrhage. The most likely sequence of events, therefore, is that the patient bled extensively from the initial jejunojejunostomy. It may be that no bleeding was found at the second operation because of the very low blood pressure at the time. The failure of response to transfusion therapy before and during the second operation is probably related to the considerable time during which the blood pressure remained at a very low level. From the evidence obtained at autopsy, the second row of sutures about the jejunum was apparently successful in preventing further hemorrhage, but fatal hemorrhage had already occurred.

The histologic picture of the kidneys will be of interest in this case, in view of the massive therapy with type-specific blood. During the 10 hours the patient was on the ward between operations, there was no recorded output of urine. During most of this time, the blood pressure was below the level necessary for renal filtration.

Microscopic observations.—The sections from the lungs showed confluent patches of bronchopneumonia. The exudate was hemorrhagic in a few foci but chiefly showed polymorphonuclear leukocytes. In another section, scattered, small areas of atelectasis were seen. Two small vessels were thrombosed. The alveolar septa were hyperemic.

Sections from the liver showed the centers of the lobules to be congested. The liver cells in these regions contained granular brown pigment (lipochrome).

The pulp of the spleen was moderately congested. The malpighian bodies were large and conspicuous, with active secondary follicles, in some of which much free and phagocytized nuclear debris was present.

The only change noted in a section from the gastroesophageal junction was autolysis of the gastric mucosa.

The epithelium lining some of the collecting tubules and Henle's loops in

the kidney showed degeneration and desquamation. With this exception, both glomeruli and tubules appeared normal.

Comment.—The degenerative changes in the kidney in this case were not pronounced and may be entirely post mortem changes. One would be more inclined, however, to attribute them to the prolonged, severe shock which this patient sustained.

The fact that this patient received 5,500 cc. of blood without histologic evidence of incompatibility is a tribute to those responsible for the transfusions. In similar cases, the experience has been quite the contrary, especially when group O blood has been given to a group A patient. (J. G. R.)

SUMMARY

In this case, postoperative hemorrhage from a jejunal anastomosis was responsible for prolonged, severe shock and eventual death. Microscopic examination of the kidneys failed to reveal the presence of pigment nephropathy, which might have been expected because of its frequency under similar circumstances. The following factors may offer a partial explanation for the absence of such a lesion: (1) The use of group-specific blood instead of the customary low-titer group O blood in the resuscitation of a group A patient, and (2) the failure of the blood pressure to reach the glomerular filtration pressure throughout the prolonged period of shock. Presumably, pigment casts do not appear unless some degree of glomerular filtration is resumed or is maintained after the initial insult.

Case 4

CLINICAL DATA

This patient received an accidental bullet wound on 4 May 1945, at 0945 hours. The wound of entrance was located at the right costal margin in the mid-clavicular line, and the wound of exit was just lateral to the inferior tip of the left scapula. When he was received in a clearing station immediately after injury, the blood pressure was 120/60 mm. Hg, and the pulse 130. He was given 125 cc. of plasma, and the 5th to 12th intercostal nerves on the right side were blocked with procaine. The patient was then moved forward with the field hospital which was in convoy at the time. Upon his arrival at the new installation, the blood pressure was 90/50 mm. Hg, and the pulse was 140.

A right thoracentesis was not productive, but 635 cc. of blood were removed from the left chest. The patient complained of extreme pain in the abdomen, right chest, and both shoulders. The response to the administration of 750 cc. of plasma and 635 cc. of blood by autotransfusion was poor.

Epidural block with procaine was performed, with good results, but severe bilateral pains in the shoulders persisted. When the patient was turned on his side before this procedure, there was a transitory fall in the blood pressure, but the block was accomplished without difficulty. Just before operation, the blood pressure was 84/50 mm. Hg. The patient's blood belonged to group B.

Gas-oxygen-ether endotracheal anesthesia was begun at 1815 hours. The wound of exit was debrided, and a thoracotomy was performed through the left ninth intracostal space, with resection of a fragment of the ninth rib. Splenectomy and suture of a laceration of the greater curvature of the stomach were carried out through a transdiaphragmatic incision. Laparotomy was then performed, with closure of a perforation in the upper portion of the lesser curvature of the stomach. The missile track had traversed the left lobe of the liver.

Just before thoracotomy, when the patient was turned on his right side, there was a marked fall of blood pressure. Within a short time, he was given 1,500 cc. of whole blood and 250 cc. of plasma. The agglutinin titers of the blood which he received at this time were not known; no blood with known agglutinin titer was available.

On 5 May, the day after wounding, the patient's condition was poor, because of atelectasis of the left lung. After tracheal aspiration, there was an increased density of breath sounds on the left side and a lessening of cyanosis. The abdomen was flat. There was considerable drainage of bile. Approximately 600 cc. of bloody fluid drained from the left chest. The hematocrit was 37 and the hemoglobin 13 gm. percent; the plasma protein was 5.8 gm. percent. The systolic blood pressure was 85-90 mm. Hg. Intravenous fluids consisted of 500 cc. of plasma and 500 cc. of blood. The urine output since operation was 700 cc. The serum showed no evidence of hemolysis.

On 6 May, the patient was somewhat improved after tracheal aspiration, with removal of dark, blood-tinged mucus. Aeration of the left chest was better, but a beginning pneumonitis was suspected. The temperature was 101°-102° F. by rectum. The urinary output was 200 cc.; albumin 1 plus was present. The blood pressure was 100/60. The patient was irrational and required sedation, for which paraldehyde was used. He perspired profusely, and venous distention was pronounced. All fluids were discontinued.

On 7 May, the left chest was clearing. Bronchial breath sounds were heard over the right base. Oxygen was administered by mask.

At 1300 hours, the patient was moved to the X-ray table. Here he rapidly became cyanotic, in spite of continued oxygen administration, and failed to respond after endotracheal suction. The superficial veins were greatly distended. He died 7 May 1945 at 1400 hours, about 76 hours after wounding.

AUTOPSY

Autopsy was performed 1 hour and 15 minutes after death (Adelstetten, Germany).

Gross observations.—There was considerable evidence of dehydration. The veins of the arms and neck were quite distended. In addition to the healing surgical incisions, the wound of entry lay just inferior to the right costal margin, and the wound of exit was at the level of the ninth rib just lateral to the tip of the left scapula.

The peritoneal cavity contained a small amount of clotted blood. The surfaces were smooth and glistening and there was no general fibrinopurulent

exudate. Along the drainage tracks to the posteroinferior aspect of the liver and the anterior portion of the stomach was a moderate deposit of yellow, fibrinopurulent exudate. There was no fluid or bile in the subhepatic space. The diaphragm was at the level of the fifth rib bilaterally.

The right chest contained about 75 cc. of clotted blood. A moderate amount of air escaped from the left chest when the cavity was opened and pressure was applied to the sternum. The chest on this side contained 400 cc. of bloody, turbid fluid, which was enmeshed in fibrinous strands and which compressed the lung more or less uniformly. Anteriorly, a fibrinopurulent-lined pocket was present, with a capacity of approximately 250 cc.; it appeared to have contained air. The left diaphragm was sutured without leakage.

The pericardial cavity contained about 40 cc. of clear, straw-colored fluid. The heart appeared considerably distended, especially on the right. The right auricle was distended by blood, which brought the trabeculae into sharp relief. The tricuspid valve measured 13.0 cm. in circumference. There were scattered subepicardial petechiae, chiefly over the posterior cardiac aspect along the coronary sulcus.

The left lung was moderately reduced in size and air content. The surface was covered by a shaggy, yellow-pink, fibrinopurulent exudate in which were embedded foreign particles with the appearance of food. Both lungs were greatly congested and edematous, particularly in the dependent portions. Edema was more severe on the right, and the right lung was somewhat heavier than the left. Both, however, were considerably increased in weight. Section of the right lung revealed it to be practically airless. Dark, serosanguineous fluid oozed freely from the cut surface. The right lower lobe contained no areas of consolidation, but small areas of early consolidation were present in the subpleural portion of the right upper lobe. There was no consolidation of the left lung, but all bronchi contained a copious, blood-tinged, serous fluid streaked with purulent exudate. No demonstrable isolated bronchial obstruction existed; rather, obstruction was generalized. There was moderately severe contusion of, and hemorrhage into, the parenchyma of the inferior portion of the left lower lobe.

The liver was not generally remarkable. The missile had entered the left lobe at the falciform ligament anteriorly and had emerged near the lesser curvature of the stomach. There was the usual degree of infarct necrosis along the missile track. There was no gross evidence of suppuration.

There were two sutured perforations of the fundus of the stomach; no leakage was noted along either suture line.

The kidneys, which were similar in appearance, were both considerably swollen, particularly in the anteroposterior diameter. The smooth cortical surface was pale yellow gray and faintly mottled. On section, the bulging cortex appeared pale and opaque. The pyramidal striations were moderately increased. The renal pelves and vessels were negative.

Gross anatomic diagnosis.—(1) Bullet wound of left thoracoabdominal area, with moderately severe perforating wound of left lobe of liver; severe

perforating wound of stomach with acute fibrinopurulent peritonitis localized to subhepatic region; laceration of spleen, splenectomy; healing perforation of left posterolateral diaphragm; severe contusion of lower lobe of left lung; complete compound fracture of left ninth rib; (2) severe left fibrinopurulent pleuritis, secondary to perforating wound of stomach and perforation of left diaphragm; (3) moderate partial left pneumothorax secondary to contusion of lower lobe of left lung and complete compound fracture of left ninth rib; (4) possible hemoglobinuric nephropathy or shock kidney, as manifested by severe bilateral pulmonary congestion and edema; acute congestive heart failure, predominantly right sided; clinical oliguria; and (5) acute purulent early bronchopneumonia of upper lobe of right lung.

Comment.—No group O blood in which the agglutinin titer had been determined was available for this patient. The only blood which could be used did not fall into the category of low-titer blood. Under such circumstances, autotransfusion would ordinarily have been particularly desirable, but in this case, because of the injury of the stomach with soiling of the left pleura, it was incorrect.

This patient appeared to have been extremely sensitive to changes in position. On two separate occasions, the blood pressure fell sharply when he was turned on his side. Before thoracotomy, the blood pressure remained at excessively low levels for a period of about 80 minutes, in spite of liberal transfusion therapy. During such periods, the renal blood flow must be markedly reduced, and it is suggested that this was a crucial factor in the production of pigment nephropathy in this case.

The delay before operation was unusually long. Part of it was caused by the fact that the field hospital was in process of moving when the patient reached the clearing station. During the delay, his condition deteriorated considerably, and liberal replacement therapy was necessary before operation. Unfortunately, however, operation was not urged at the earliest possible moment because of the mistaken belief that there had been no perforation of a hollow viscus. Obviously, the optimum time of operation would have been when the patient first reached the clearing station, only a short time after injury.

Microscopic observations.—In one section of the lungs, the tissue was packed with red blood cells. Several vessels contained thrombi. In another section, the congestion was almost as severe, and the bronchiolar walls contained a purulent exudate. In a third section, which was free from congestion, the alveolar walls showed patchy approximation and stretching. There was a fibrinopurulent exudate on the pleura.

Rare round cells were found beneath the epicardium. No myocardial changes were noted.

In one section of the liver was a large zone of infarct necrosis, bordered by a region of inflammatory exudate, beyond which was normal-appearing liver tissue. The peritoneal surface showed a thick, purulent exudate. Both in the infarcted area and in the exudate were masses of bacteria.

Sections from the kidneys showed amorphous material and lightly staining spherical bodies in capsular spaces and proximal convoluted tubules, which were moderately dilated. Brown, granular casts were present in the distal tubules and loops of Henle. Nuclear pyknosis and cell shrinkage were noted in relation to these casts. There was moderate swelling of the capsular and convoluted tubular epithelium. A few cysts filled with pink-staining coagulum were present.

One zone of cortical necrosis was noted in the adrenal glands. Otherwise, there was a decrease in the usual vacuolar appearance of the cortical cells. Adjacent fat tissue showed regions in which cells had lost their vacuolated structure.

Microscopic diagnosis.—(1) Focal necrosis of the adrenal gland; and (2) moderately severe, early hemoglobinuric nephrosis.

Comment.—The microscopic findings are in general agreement with the gross findings. Although the kidney lesion was classified as hemoglobinuric nephrosis, death appears to be related to trauma, peritoneal infection, and pulmonary circulatory obstruction rather than to uremia.

SUMMARY

This patient affords an example of a severe thoracoabdominal wound in which the military exigency afforded an opportunity to observe the steady deterioration which can be caused in a wounded man's condition by the delay in operation. Resuscitation and operation were made much more difficult in this case by the passage of a relatively short period of time. Failure to realize that a wound of the stomach was present was partly responsible for the delay and was also responsible for the use of autotransfusion in the presence of contamination of the pleura by gastric contents.

Microscopic examination confirmed the presence of pigment nephropathy, which accounts for the oliguria and gross anatomic changes in the kidneys. Pulmonary edema and mild congestive heart failure were again noted as a terminal manifestation of the renal failure which follows severe traumatic shock.

Case 5

CLINICAL DATA

This patient received a bullet wound of the left buttock 1 June 1944, at 0300 hours. He was given 15 mg. of morphine tartrate at 0305 hours and was brought to the collecting station at 0600 hours. Here his wound was re-dressed, in preparation for evacuation to the rear. The record indicates that he seemed in relatively good condition, but at 0630 hours, while he was urinating, he lapsed into deep shock and stopped breathing. After the use of artificial respiration and the administration of 1,750 cc. of plasma, supplemented by two large doses of caffeine sodium benzoate, breathing was resumed. At this time (0815 hours), it was noted that the left pupil was dilated and that there was

weakness of the face on the left side, with equivocal aphasia. At 0900 hours, improvement was continuing, and at 0930 hours the patient was sent to the rear. He reached the clearing station at 1000 hours and was taken at once to the field hospital. At 1005 hours, his blood pressure could not be obtained by auscultation or palpation. In spite of a plasma transfusion and oxygen inhalations, he continued poorly oriented. Death occurred at 1200 hours. The left pupil was notably larger than the right.

This patient had received a total of 500 cc. of plasma in the field hospital. He expired just as whole blood was obtained. His blood pressure was not obtainable at any time after he reached the field hospital.

AUTOPSY

Autopsy was performed 2 hours after death (Cori, Italy).

Gross observations.—Externally the body was not remarkable except for extreme pallor.

The brain was negative, except that the cerebral vessels were exceedingly pale. There was no gross area of infarction. The lungs were negative, except for some patchy atelectasis.

The peritoneal cavity contained an enormous quantity of blood, estimated at 4,000 to 5,000 cc. The source was the left hypogastric artery, which was transected at the point at which it crosses the brim of the pelvis. There was a large hematoma in the areolar tissue of the retroperitoneal space and along the course of the missile, which was through the medial aspect of the ramus of the ischium. A second fragment of the bullet lay free in the left upper quadrant of the abdomen. The mesentery of the sigmoid colon and a loop of the mesentery of the small bowel were perforated, and there were two perforations of the jejunum. It was impossible to judge the amount of fecal contamination of the peritoneum with any accuracy because of the large amount of blood present in the peritoneal cavity. Contamination, however, was not thought to be great.

Gross anatomic diagnosis.—Bullet wound of abdomen, entering by way of left buttock, with laceration of left hypogastric artery and exsanguinating intraperitoneal hemorrhage; two perforations of jejunum; compound comminuted fracture of ramus of left ischium.

Comment.—There is no reasonable doubt in this case that death was caused by massive intraperitoneal hemorrhage. The cerebral changes were due to the severe degree of cerebral anoxia. It is regrettable that whole blood was not available at the time this man reached the field hospital, although its liberal use might not have changed the outcome in the face of longstanding and profound shock.

Microscopic observations.—Examination of sections from the lung showed extensive alveolar atelectasis with overdilatation of the respiratory bronchioles. This finding is consistent with a story of prolonged artificial respiration. A

few fat droplets were found in small arteries and arterioles, but the number was not sufficient to make them of functional significance.

The choroid plexus appeared edematous. The kidney and brain were negative.

SUMMARY

This case illustrates several important points in connection with shock among battle casualties.

1. It may be exceedingly difficult to detect the fact that severe circulatory collapse is about to occur, particularly when hemorrhage is in progress.

2. Once the blood volume has reached a critical level, a relatively minor happening, in this instance the act of sitting up to urinate, may be followed immediately by the onset of profound shock.

3. It is almost impossible to treat shock caused by severe and progressive hemorrhage with plasma alone.

4. Laparotomy to control hemorrhage offers the only hope of success in such a case as this, and yet, as in this case, it may be impossible to prepare the patient adequately for operation in the face of severe bleeding.

Case 6

CLINICAL DATA

This patient, who was 22 years of age, received a shell-fragment wound of the left buttock 3 October 1944, at 2230 hours. After a delay of unknown duration, he was brought to a field hospital in profound shock. Even after he had received 250 cc. of plasma and 2,500 cc. of group O blood (it is believed that his blood belonged to group AB), the blood pressure was only 98/60 mm. Hg and the pulse was 130, but operation was begun without further delay because intra-abdominal hemorrhage was suspected. The patient received 50,000 units of penicillin intramuscularly, but no sulfonamides were given in the field hospital.

Exploration of the abdomen revealed multiple perforations of the small and large bowel. In the peritoneal cavity, there was an estimated 1,000 to 1,500 cc. of blood which was found to have come from the region of the bladder on the left side posteriorly. The retroperitoneal space was opened, and, after considerable difficulty, the bleeding was brought under control by the ligation of two branches of the left internal iliac vein. The perforations of the small bowel were sutured, and a sigmoid colostomy was performed through the left lower quadrant of the abdomen. The gluteal wound was debrided.

The patient was in a critical state throughout the operation. In spite of the administration of 4,000 cc. of group O blood and 750 cc. of plasma, his blood pressure was often as low as 40/0 mm. Hg, and at the end of the operation, which took 4 hours, the blood pressure was only 90/48 mm. Hg.

On the first postoperative day, the blood pressure was 100/50 mm. Hg. The urine was deep red brown and contained 2 to 3 red blood cells per high-power field.

The second day after operation, the blood pressure was 120/70 mm. Hg. The patient was moderately dyspneic. Examination of the abdomen revealed no evidence of peritonitis. Catheterization produced only 10 cc. of urine. Isotonic glucose solution and 500 cc. of a 2-percent solution of sodium bicarbonate were given intravenously.

On the third postoperative day, dyspnea was severe. The patient was drowsy, and his speech was slurred. The blood pressure was 180/100 mm. Hg. Moist rales were first noted throughout both lungs about 2½ hours before death. Dyspnea rapidly worsened, and death occurred at 1830 hours 5 October 1944, 44 hours after wounding. The total output of urine from the beginning of operation until death was about 210 cc.

AUTOPSY

Autopsy was performed 12 hours after death (Elaves, France).

Gross observations.—The peritoneal cavity contained 200 cc. of bloody fluid. There was no exudate other than the generalized matting of loops of small bowel by fibrin. In the pelvis was a small amount of clotted blood. The lungs were indurated and edematous. Only the kidneys were saved for microscopic study. They were somewhat swollen and appeared to be congested. Small subcapsular hemorrhages were scattered over both renal surfaces, but on section it was found that they did not extend into the cortex. The cut surfaces of the kidneys were rather pale.

Gross anatomic diagnosis.—(1) Perforating shell-fragment wound of abdomen with multiple perforations of ileum, multiple perforations of sigmoid colon, and multiple lacerations of branches of left internal iliac vein; and (2) pigment nephropathy, hemoglobinuric type, possibly due to massive transfusion of group O blood, with severe pulmonary congestion and edema, manifest clinically by severe oliguria, moderate arterial hypertension, and severe pulmonary edema.

Comment.—Although the blood group of this patient is not positively known, it is believed that his blood belonged to group AB. If this be true, his AB cells were susceptible to agglutination and hemolysis by the anti-A and anti-B iso-agglutinins found in the plasma of group O blood. The difficulty of providing enough group-specific blood is apparent, as are the shortcomings of universal donor blood under such circumstances.

Microscopic observations.—Examination of the kidney tissue revealed that a very large number of collecting tubules, and a smaller number of distal convoluted tubules, were plugged with pigmented casts. There was slight dilatation of the proximal nephrons. The interstitial tissues were slightly edematous. In some areas, proliferation of the tubular epithelium was evident, the casts being encapsulated within the tubules. Here and there, small granulomas had formed in the interstitial tissues. There were scattered foci of lymphocytic infiltration.

Microscopic diagnosis.—Severe hemoglobinuric nephropathy.

SUMMARY

This case provides another example of posttraumatic renal failure, with the microscopic finding of pigment nephropathy. Although definite proof is not available, it is believed that the transfusion of a large volume of group O blood contributed to the production of the renal lesion. Perhaps, in the presence of severe shock, the kidney is particularly liable to injury by a relatively small amount of hemoglobin in the plasma. A moderately severe degree of hypertension was observed before death; its possible relationship to the pathologic physiology of renal failure is of considerable interest.

Case 7

CLINICAL DATA

This patient, a German prisoner of war with a bullet wound of the abdomen, was first seen 6 March 1945 at 1430 hours. The precise time of wounding was unknown but was probably several hours earlier. He reached a field hospital at 1715 hours, after having received 750 cc. of plasma. At this time, he was in profound shock, and his blood pressure could not be obtained. He was stuporous and at times semidelirious, and his appearance was striking because of a peculiar cherry-red flush of the face and extremities and a red mottling of the skin of the trunk. He was moderately dehydrated. The response to 1,500 cc. of plasma and 1,500 cc. of blood was poor; the blood pressure rose only to 78/40 mm. Hg, and no clinical improvement was evident. His blood group was O.

Operation was begun 6 March at 2210 hours. Laparotomy revealed extensive contamination of the peritoneal cavity by 2,000 cc. of bloody fecal material. There were multiple perforations of the jejunum, and the transverse colon was found almost completely torn away from its attachments except for a narrow band of tissue along the mesenteric border. It was necessary to resect about 15 cm. of the small bowel; three perforations in the jejunum were sutured, and a colostomy was performed. The patient received 1,000 cc. of whole blood during the operation.

At the conclusion of the operation, the blood pressure was at a very low level, and there was never any significant rise. Often it was unobtainable. The patient was stuporous, and death occurred 11 hours after operation.

AUTOPSY

Autopsy was performed 4 hours after death (St. Avoird, France).

Gross observations.—The mottled, pink-gray discoloration of the skin of the trunk noted before operation was still present.

The peritoneum showed the effects of severe contamination. A small amount of seropurulent fluid was present. The serosal surfaces of the bowel were opaque, dark and congested, and patches of fibrinopurulent exudate were present.

The heart was rather soft. The right side was distended by blood.

The pleural cavities were not remarkable, except for an old fibrous pleuritis at both bases.

Both lungs showed considerable hypostatic congestion and partial atelectasis of the dependent and inferior portions.

There was a moderately large laceration of the left lobe of the liver.

The spleen was about three times the usual size and was dark purple red. The consistency was firm. The pulp, which was uniformly dark purple, did not scrape away easily.

The gastrointestinal tract showed the sutured lacerations and anastomoses of the small bowel already described.

The kidneys were of the same size, but the right kidney appeared somewhat more congested and purple than the left. The cortical surfaces of both kidneys showed focal punctate hemorrhagic areas, more marked on the right side. On section, these hemorrhagic areas were seen to extend varying distances into the cortex in the form of small, blood-suffused columns. On section, the parenchyma bulged above the cut edge of the capsule. A few petechiae were present in the mucosa of the renal pelvis.

The cortex of the left adrenal gland exhibited several radial hemorrhagic areas in which there was possibly destruction or necrosis of the tissue. The medullary area was negative.

Gross anatomic diagnosis.—(1) Perforating gunshot wound of abdomen, with severe laceration and avulsion of transverse colon; multiple perforations of small bowel; moderately severe laceration of left lobe of liver; (2) severe generalized peritonitis, secondary to injuries of transverse colon and small bowel; (3) extensive hemorrhagic focal necrosis of kidneys and possibly of left adrenal, causes unknown; (4) moderately severe splenomegaly, possibly secondary to massive transfusion therapy and peritonitis; and (5) hypostatic pulmonary congestion and edema, with bilateral partial atelectasis.

Comment.—The exact lapse of time between wounding and operation in this case was unknown but seems to have been at least 16 to 18 hours. The patient was moribund on admission, as the result of shock and extreme peritoneal contamination.

The case illustrates the difficulty which occasionally was encountered in the management of patients with overwhelming contamination of the peritoneum. Once contamination of this degree has occurred, effective therapy is difficult even though the patient is seen relatively soon after wounding.

The peculiar gray-pink mottling of the skin suggests a considerable degree of capillary damage. The pathogenesis of the hemorrhagic columns in the renal cortex is obscure, but is possibly related to the severity of the shock and infection.

Microscopic observations.—There were a few atelectatic patches in the lungs. The alveolar septa were hyperemic. The bronchial walls were infiltrated with lymphocytes. One small artery was thrombosed. Another section showed scattered small areas of hemorrhage into the peribronchial alveoli.

The centers of the lobules of the liver were congested. The portal triads were infiltrated with moderate numbers of lymphocytes.

The malpighian corpuscles had active germinal centers; many contained foci of degeneration, with nuclear debris. The pulp and sinuses were engorged with blood.

A moderate number of distal convoluted and collecting tubules in the kidneys contained pigmented casts. Protein precipitate was seen in many of the convoluted tubules. Some of the tubules contained hyalin casts. Neither inflammatory reaction nor edema was present in the interstitial tissues. A small number of basophilic structures, probably sulfonamide crystals, were seen. Vascular congestion was pronounced.

There was pronounced congestion of both the inner zone of the cortex and of the medulla. Small foci of lymphocytes were seen in the medulla.

The serosal layer of the intestine was thickened and edematous. It was infiltrated with lymphocytes, histiocytes, and polymorphonuclear leukocytes. The mucosa was covered with blood, serum, and epithelial debris.

Microscopic diagnosis.—(1) Hemoglobinuric nephropathy, moderately severe; and (2) focal necroses in spleen.

Comment.—In the absence of other factors which produce pigmented casts in the renal tubules, the renal lesion in this case must be attributed to the blood transfusions which the patient received. His blood group was O, and he received 1,500 cc. of O bank blood. If the blood typings were correct, the crossmatches negative, and the blood free of hemolysis before transfusion, there is no evident explanation for the nephropathy. (J. G. R.)

SUMMARY

This patient sustained an extremely severe wound of the abdomen with widespread peritoneal contamination, and his status on arrival at a field hospital reflected the relatively long lapse of time since the injury. He died within a short time, in spite of replacement therapy and prompt surgical care. Failure to survive such a wound seems to depend upon (1) the severity of the hemorrhage and (2) the deleterious effects of massive peritoneal contamination. It seems likely that appropriate bacteriologic studies would have revealed significant findings in this instance.

Case 8

CLINICAL DATA

This patient received a perforating bullet wound of the abdomen 30 March 1945, at 1740 hours. When he reached a field hospital at 1945 hours, he was in profound shock, with a blood pressure of 42/20 mm. Hg and a pulse of 128. His response to 500 cc. of plasma and 1,500 cc. of whole blood was not good. At 0030 hours 31 March, his blood pressure was only 80/60. His blood group was O.

Laparotomy was performed about 4½ hours after the patient was received at the field hospital. The peritoneal cavity was full of blood, and there were perforations of the stomach and proximal ileum, as well as a laceration of the left lobe of the liver. Severe bleeding was in progress from the gastrohepatic ligament; it was stopped as promptly as possible. The perforations in the intestine were then sutured, and a large defect in the transverse mesocolon was repaired. The spleen and the left kidney, both of which were badly lacerated, were removed. The wounds of entrance and exit were debrided. Throughout the operation, the patient's condition was critical in spite of the administration of 250 cc. of plasma and 2,750 cc. of whole blood.

He failed to improve after operation and died at 0005 hours 1 April 1945, about 24 hours after operation and 28 hours after injury.

AUTOPSY

Autopsy was performed 15 hours after death (Grossostheim, Germany).

Gross observations.—There was considerable post mortem lividity of the neck and face. The abdomen was moderately distended.

The left chest contained 600 cc. and the right chest 200 cc. of blood-tinged fluid. The peritoneal cavity contained about 800 cc. of cloudy, blood-tinged fluid. The loops of small bowel were loosely bound together by strands of fibrinopurulent exudate, particularly in the vicinity of the sutured perforations of the ileum. No free purulent exudate was present in the peritoneal cavity. The adipose tissue of the colon and omentum exhibited numerous focal areas 0.5 to 1.5 cm. in diameter, of chalky, gray-white discoloration, particularly in the upper abdomen.

The heart was not remarkable except for the presence of subepicardial ecchymosis posteriorly along the coronary sulcus and over the wall of the left auricle.

The lungs were both markedly increased in weight and showed hypostatic congestion and atelectasis. The tracheobronchial tree was filled with a tenacious, blood-tinged mucoid exudate which was occasionally flecked by purulent material. Some of the smaller bronchi contained similar material. There was no evidence of established pneumonic consolidation.

The left lobe of the liver, which was the site of an extensive laceration, as well as a portion of the right lobe, was pale, yellow gray, and of abnormally soft consistency.

The body of the pancreas was partially torn away from its attachments, and there had been considerable autolysis of the contiguous tissues. The portion of pancreas adjacent to the bullet track was pale, reddish gray, and extremely soft in consistency. Surrounding this area were evidences of old hemorrhage. No purulent exudate, however, was present in the pancreatic area.

The gastrointestinal tract showed only healing sutured perforations.

Gross anatomic diagnosis.—(1) Perforating gunshot wound of left abdo-

men, with severe laceration of left lobe of liver, possible necrosis of most of left lobe and of portion of right lobe; two healing perforations of proximal ileum; laceration or contusion of body of pancreas with autolysis of pancreatic tissue and acute fat necrosis throughout peritoneal cavity; severe laceration of spleen, surgical removal; severe laceration of left kidney, surgical removal; (2) severe bilateral pulmonary atelectasis, secondary to bronchial obstruction by mucus; (3) subepicardial hemorrhage, probably due to asphyxia, secondary to pulmonary atelectasis; (4) acute fibrinopurulent peritonitis, secondary to perforating wounds of intestine and liver; and (5) moderately severe bilateral pleural effusion.

Comment.—Aside from the severe trauma to several organs, the insult of extreme pulmonary atelectasis appears to be immediately responsible for the death, which seemed inevitable from the time of wounding.

Microscopic observations.—Numerous hemorrhages were present in the fat tissue around the adrenal gland. Several small hemorrhages were also seen in the medullary portion. A portion of the cortex stained a very faint pink resembling an area of infarction. The sinusoids were congested.

Numerous hemorrhagic areas were seen in two slides of the lung tissue. Areas of atelectasis were present. Cells of the heart-failure type were present in all areas. In a third slide, the tissue was for the most part normal, but in one area were alveoli filled with protein-rich fluid in which were many erythrocytes.

Granules of brown pigment were seen in the muscle bundles of the heart. Some hemorrhage was visible in the fat of the pericardium.

Extensive areas of hemorrhage and necrosis of liver substance were observed along one side of the first slide examined. In the immediate vicinity of the traumatized area were considerable accumulations of polymorphonuclear leukocytes and lymphocytes. In some areas were evidences of small abscess formation. Numerous lymphocytes were seen in nearly all the periportal areas. In a second slide, extensive areas of tissue destruction were present. The liver cells were dark-staining cords without nuclei.

SUMMARY

The findings in this case are characteristic of the massive abdominal injuries which are by no means rare among severely wounded men. Wounds of this kind produce profound shock by destruction of tissue, hemorrhage, and massive peritoneal contamination. Death almost always occurs with little delay in spite of liberal replacement therapy and prompt surgical care. If the patient does survive the immediate postoperative period, the renal damage of the period of profound shock may prove fatal within a few days.

The microscopic observations in this case suggest that there was widespread necrosis of liver tissue which was not restricted to the missile track. Since the kidneys were not examined microscopically, the question of a renal lesion cannot be settled.

Case 9

CLINICAL DATA

This patient received a perforating bullet wound of the right buttock 30 March 1945, at 1700 hours. When he was received at the field hospital at 1945 hours, he appeared moribund; neither pulse nor blood pressure could be obtained. In the space of an hour, he was given 250 cc. of plasma and 2,500 cc. of group O blood, but the response was poor. Laparotomy was undertaken in the belief that hemorrhage was continuing. Just before operation, the blood pressure was 50/30 mm. Hg. The patient's blood belonged to group O.

Exploration of the wound track from the right gluteal fold to the right iliac fossa revealed (1) a complete laceration of the right external iliac artery and vein, (2) a complete laceration of the right gluteal artery and vein, (3) division of the right femoral nerve, and (4) a perforation of the terminal ileum. All the injured vessels were ligated, and the ileal perforation was closed. During the operation, an extensive expanding retroperitoneal hematoma was noted. At the end of the operation, the blood pressure was 70/40 mm. Hg; 2,500 cc. of group O whole blood had been given while it was in progress.

The patient's condition continued critical after operation. On the first postoperative day, the hemoglobin was 55 percent of normal; the red blood cells numbered 3,290,000 per cubic millimeter. On the second day, the volume of urine was 225 cc. On the third day, no urine was excreted. The right leg was gangrenous, with a line of demarcation just below the knee. On the fourth day, no urine was excreted. The blood pressure was 160/80 mm. Hg. Venesection was carried out for the relief of pulmonary edema, but dyspnea continued. The patient died 3 April 1945, at 1635 hours, about 96 hours after wounding.

AUTOPSY

Autopsy was performed 1 hour and 25 minutes after death (Grossostheim, Germany).

Gross observations.—The sclerae were slightly icteric. There was considerable brawny edema of the whole of the right leg, with an effusion into the knee joint and beginning dry gangrene below the knee.

The pericardial and pleural cavities contained small amounts of straw-colored fluid. There was a large bilateral retroperitoneal hematoma, which was larger on the right. Blood had disseminated upward as high as the perirenal tissue bilaterally and downward to fill the areolar tissue about the bladder. The right external iliac artery and vein and the right gluteal artery and vein had been ligated.

The heart was pale. Subepicardial petechial hemorrhages were distributed over the surface. The right ventricle was unusually soft. The tricuspid valve measured 13.5 cm., the mitral valve 10.3 cm., and the aortic valve 5.8 cm. The coronary vessels were normal.

Both lungs were partially atelectatic. The cut surface was very wet and exuded a large quantity of serosanguineous fluid. The bronchi were filled with edema fluid.

The liver was apparently slightly increased in size, but on section the parenchyma was not remarkable.

The spleen was moderately increased in size. The consistency was somewhat softer than normal and the malpighian bodies were prominent.

The gastrointestinal tract was negative, apart from a healing laceration of the ileum.

The kidneys, both of which presented the same appearance, were somewhat smaller than usual. The surfaces were smooth and were deep purple red, with a peculiar, finely mottled, nutmeg appearance. On section, the cortex was somewhat pale in comparison to the color of the renal surface. The peripheral portions of the pyramids as seen on section were dark, due to the presence of fine, closely placed, red-brown striae. The renal vessels were negative.

Gross anatomic diagnosis.—(1) Perforating bullet wound of abdomen via right buttock, with laceration of right external iliac artery and vein, laceration of right gluteal artery and vein, division of right femoral nerve, healing perforation of terminal ileum, and incomplete fracture of right ilium; (2) severe retroperitoneal hemorrhage, secondary to laceration of iliac vessels; (3) edema and dry gangrene of lower right leg, secondary to ligation of iliac and gluteal vessels; (4) pigment nephropathy possibly due to shock and ischemia of right leg, as evidenced clinically by oliguria, slight hypertension, and pulmonary edema; (5) pulmonary congestion, bilateral, severe, with partial atelectasis, possibly due to uremic pneumonitis and left heart failure secondary to pigment nephropathy; (6) multiple petechial subepicardial hemorrhage; and (7) icterus, slight.

Comment.—This case epitomizes the outcome in many patients who have suffered severe shock for long periods of time. In such instances, the ultimate decline is manifest chiefly as cardiorenal decompensation with increasing pulmonary edema, particularly when relatively large quantities of fluid are given. Ischemic muscle necrosis, massive transfusion therapy, and the extensive retroperitoneal hematoma present in this case may have contributed to the pigment which will almost certainly be found in the renal tubules on microscopic examination. Whatever may be the source of the pigment, it would appear that in this case the severe degree of shock was the most important factor in the development of the renal lesion.

The blood which this patient received was fresh; it was drawn in the field hospital just before it was administered. All flasks were inspected for hemolysis, and none was apparent. Routine crossmatchings showed no incompatibility, and the group of all the blood used was carefully checked just before transfusion.

Microscopic observations.—A few small areas in the pulmonary alveoli contained fibrin and a few polymorphonuclear and mononuclear cells. The interlobular septa were edematous. On frozen section a large number of fat emboli were observed in the alveolar capillaries and arterioles.

The portal triads were infiltrated with moderate numbers of lymphocytes and eosinophiles.

The pulp of the spleen was moderately congested. There were increased numbers of eosinophiles in the malpighian bodies.

A very large number of the distal convoluted and collecting tubules in the kidney sections were plugged with pigmented casts. Sulfonamide crystals were seen here and there in the tubules. A few small foci of lymphocytes were found in the interstitial tissues. Epithelial proliferation had occurred about some of the casts in the pyramid. No fat emboli were seen on frozen section.

Sections of the pancreas showed cystic dilatation of a small number of acini, which contained pink-staining material.

Microscopic diagnosis.—(1) Severe pulmonary fat embolism; and (2) severe pigment nephropathy, hemoglobinuric type.

SUMMARY

Because of his severe vascular injury and the resulting hemorrhage, this patient remained in shock for a prolonged interval. In spite of the fact that resuscitation and operation were accomplished with a fair degree of success, postoperative oliguria occurred, and death followed, from pulmonary edema, on the fourth day after operation. Microscopic examination confirmed the presence of pigment nephropathy and revealed, in addition, a high degree of pulmonary fat embolism. It is suggested that the fat embolism may have been the more important factor in the pulmonary edema which occurred on the fourth day after operation. It seems unlikely, however, that this patient could have survived the renal lesion.

The amount of trauma to the bone appears to have been relatively mild in this case, and it may be that injury of gluteal adipose tissue contributed to the pulmonary embolism.

Case 10

CLINICAL DATA

This patient received a perforating shell-fragment wound of the thorax and abdomen 14 December 1944, at 1020 hours. When he reached a field hospital at 1245 hours, the blood pressure was 80/34. Hg, the pulse was 140, and he was in moderately severe shock. He complained of shortness of breath and of right-sided chest pain. The wound of entry was at the left lateral costal margin and the wound of exit in the fourth interspace in the right anterior axillary line. Right thoracentesis produced 960 cc. of blood. The right 4th to 12th intercostal nerves were infiltrated with procaine, and pain in the chest lessened. At 1525 hours, after the administration of 500 cc. of plasma and 1,000 cc. of whole blood, the blood pressure was 122/64 mm. Hg. A catheterized specimen of urine showed occasional erythrocytes.

Thoracotomy was begun at 1600 hours, under endotracheal gas-oxygen-ether anesthesia. The thorax was opened in the right fifth interspace, and fragments of the fifth costal cartilage were removed. Five hundred cubic centimeters of blood were aspirated from the right pleural cavity. A small laceration

of the lower lobe of the right lung was closed with a mattress suture. After a 6-cm. laceration of the right diaphragm had been sutured, the thoracotomy incision was closed. The sucking wound of the anterior right chest was debrided and closed.

Laparotomy revealed much blood in the peritoneal cavity. The source appeared to be the severely lacerated and comminuted left lobe of the liver. There was an extremely severe laceration of the left transverse colon, which involved about three-fourths of its circumference for a distance of 7 cm. This portion of the large bowel was exteriorized through a left subcostal incision. No perforations were evident in the remainder of the gastrointestinal tract, and at this time there was no evidence of an acute inflammatory process within the peritoneal cavity. The spleen and kidneys were not injured. During the course of the operation, the patient's condition remained poor, although he received 1,500 cc. of whole blood, 750 cc. of plasma, and an autotransfusion of the 960 cc. of whole blood which had been aspirated from the right chest before operation. The operation required 2 hours.

Immediately after operation, the blood pressure was 40/0 mm. Hg, the pulse 104, and the respiration 24. The respirations were described as gurgling. The patient reacted from anesthesia at 0100 hours 15 December 1944, but respirations ceased at 0625 hours, about 20 hours after wounding.

AUTOPSY

Autopsy was performed 7 hours after death (Meisenthal, France).

Gross observations.—The peritoneal cavity contained 300 cc. of foul-smelling, bloody fluid. There was an extensive laceration of the left lobe of the liver. The omentum, which was dirty and hemorrhagic, was displaced about the colostomy. Gentle pressure upon the stomach caused leakage of gas and gastric contents through a small aperture in the midportion of the omentum just inferior to its attachment to the greater gastric curvature. The loops of small bowel, particularly those in the lower portion of the peritoneal cavity, exhibited evidences of marked peritoneal contamination. The serosa was injected, bright red, and more opaque than normal. No fibrinopurulent exudate was recognized.

The right pleural cavity contained 300 cc. of blood, but there was relatively little fibrinous exudate. There was a defect in the fifth costal cartilage and a fracture of the sixth costal cartilage on the right.

The heart was somewhat dilated. The myocardium was softer than usual in consistency.

The appearance of both lungs was the same. They were considerably increased in weight and exhibited generalized atelectasis and loss of resiliency. The laceration of the right lower lobe had been closed, and contusion of the pulmonary parenchyma was not marked. On section, much blood and serous fluid dripped from the cut surfaces. The main bronchi and their smaller branches were occluded by a tenacious, mucosanguineous exudate which appeared to be responsible for the observed atelectasis. There was no evidence

of bronchopneumonia, but some of the smaller bronchi contained moderate amounts of mucopurulent exudate.

The spleen was small and soft but not otherwise remarkable.

The liver was of normal size. There was marked destruction of the left lobe, but no evidence of suppuration, and little autolysis was observed along the track of the missile. No exudate was present, nor was there a discernible zone of leukocytic infiltration. Thrombosis of the hepatic veins was noted only in the immediate vicinity of the laceration and was not striking. On section, the right lobe of the liver was not remarkable.

The stomach was greatly distended by partially digested food. There was a small (8-mm.) unsutured perforation in the greater curvature 10 cm. proximal to the pylorus. The contamination of the lesser peritoneal sac was minimal, and gastric contents appeared to have been extruded into the main peritoneal cavity through a small perforation in the omentum. A small (3-mm.) perforation of the ileum was located about 90 cm. from the ileocecal valve.

The kidneys were not enlarged, but the smooth cortical surfaces were pale, and on section the cortex showed faintly hemorrhagic markings through the pale yellow-gray substance. The renal pyramids were faintly striated by red-brown markings and had a peculiar pale-pink coloration.

Gross anatomic diagnosis.—(1) Thoracoabdominal shell-fragment wound, with entrance at left costal margin and exit via right chest at level of fifth costal cartilage, with small perforation of greater curvature of stomach; small perforation of terminal ileum; severe laceration of transverse colon, loop colostomy; severe laceration and comminution of left lobe of liver; sutured perforation of right leaf of diaphragm; moderately severe laceration of lower lobe of right lung, closed; multiple compound fractures of right fifth and sixth costal cartilages and left sixth and seventh costal cartilages; (2) severe bilateral bronchial obstruction with pulmonary atelectasis; (3) acute generalized peritonitis, secondary to perforating wounds of stomach, terminal ileum, and transverse colon; (4) moderate right hemothorax, secondary to thoracoabdominal wound; and (5) congestion and edema of lungs, probably secondary to bronchial obstruction and atelectasis.

Comment.—The severe laceration of the liver and the extreme peritoneal contamination were ominous findings at operation. It is remarkable, however, that there was so little evidence of peritonitis at this time. A severe fibrinopurulent peritonitis was present at autopsy. The difference was perhaps due simply to the passage of time, though it must be remembered that unclosed perforations of the stomach and ileum had permitted additional contamination of the peritoneal cavity.

The large amount of bloodstained mucoid exudate present in the bronchi at autopsy was remarkable. It did not seem reasonable to try to account for it simply on the basis of the contusion of the right lung. The severe atelectasis appears to have been immediately responsible for death, and its development may have been favored by the fact that after operation the patient received two injections (each of 0.008 gm.) of morphine sulfate.

The use of autotransfusion under the circumstances of this case constituted an error of judgment. In the presence of a large wound of the colon, the blood could scarcely have escaped contamination, and its use undoubtedly contributed to the fatality.

Microscopic observations.—The lung tissue showed large areas of atelectasis. The alveolar septa were hyperemic. Many pigmented macrophages were seen within the alveoli.

One section of the liver was essentially normal. The other showed extensive traumatic infarction.

Examination of the spleen showed the malpighian bodies to be numerous and large and the pulp slightly congested.

A few cystic tubules in the kidney were lined with flattened epithelium containing pigmented material. The epithelial cells in some of the collecting tubules contained granules of golden-brown pigment. A single focus of lymphocytes was seen in the interstitial tissues.

One of the interlobular septa seen in the section from the pancreas was infiltrated with polymorphonuclear leukocytes and a few histiocytes.

A section of voluntary muscle showed hemorrhage and polymorphonuclear leukocyte infiltration into the tissues between the muscle bundles.

A small amount of purulent exudate covered a small area in the serosa of the jejunum. In the spaces between the valvulae conniventes were desquamated and necrotic epithelial cells. The mucosa was infiltrated with a moderate number of lymphocytes and a few eosinophiles.

Section from the stomach showed hemorrhage into the submucosa and many mononuclear cells containing formalin-pigment (formaldehyde pigment) precipitate. In one small area was a collection of polymorphonuclear leukocytes.

SUMMARY

This is an example of a very severe thoracoabdominal wound in which death occurred within a relatively short time after injury. Extreme destruction of the liver and widespread peritonitis appear to have been the most important factors in the fatality. The patient's critical state and the widespread visceral damage explain why two small perforations of the gastrointestinal tract were missed at operation. Other important lethal factors were undoubtedly the continuing peritoneal contamination, the autotransfusion of contaminated blood, and the rather liberal administration of morphine.

Case 11

CLINICAL DATA

This patient received a shell-fragment wound of the abdomen 17 October 1944 about 1130 hours. When he reached a field hospital at 1350 hours, his blood pressure was 128/70 mm. Hg, and his condition appeared surprisingly good. The foreign body had entered the abdominal cavity through the right

upper quadrant and had made its exit through a large defect in the left upper quadrant, with the evisceration of 14 to 16 cm. of the transverse colon, several loops of small bowel, and most of the omentum. Two hundred and fifty cubic centimeters of plasma were administered rapidly, and a transfusion of group O whole blood was begun. During roentgenologic examination, after he had received about 300 cc. of blood, the patient had a chill. The transfusion was stopped immediately, and a second flask of blood was substituted for the first. On the operating table, shortly after the chill, the blood pressure was 90/60 mm. Hg, and operation was deferred until it reached 124/70 mm. Hg. This delay amounted to about 2 hours.

Laparotomy revealed a small amount of blood and some bile in the peritoneal cavity. There was a large laceration of the liver, a perforation of the second portion of the duodenum, a perforation of the midjejunum, and multiple perforations of the transverse colon. The duodenal perforation was sutured, and posterior gastroenterostomy performed. The jejunal perforation was sutured. A segment of the colon was exteriorized. It was noted that during operation bleeding tended to be excessive and hemostasis was difficult. Before the abdomen was closed, 50,000 units of penicillin were placed in the peritoneal cavity.

The patient's condition was so critical after operation that he was immediately given 1,000 cc. of blood. The blood pressure had fallen to 90/60, and shortly afterward it fell to 80/50 mm. Hg. The day after operation, the exteriorized colon was opened; its appearance was not remarkable. Coarse rales appeared in the chest, and considerable quantities of purulent material were aspirated from the trachea. Death occurred 19 October 1944, about 48 hours after operation.

During this period of survival after injury, this patient received a total of 3,000 cc. of plasma and 3,500 cc. of blood. Before the first plasma transfusion was started, a sample of blood was taken. The group was O, and all the blood which he received was compatible by routine crossmatching.

AUTOPSY

Autopsy was performed 2 hours after death (Lunéville, France).

Gross observations.—The right pleural cavity contained 200 cc. of serous fluid. The peritoneal cavity contained 300 cc. of thin, purulent exudate. A generalized fibrinopurulent peritonitis was present. There apparently had been no appreciable hemorrhage from the liver after operation, and the serous surfaces were not bilestained. Neither the sutured lesions of the intestine nor the gastroenterostomy was remarkable. The colostomy was also not remarkable. There was a large defect of the anterior peritoneum medial to the colostomy in the left upper quadrant, and there appeared to be an early infection in the properitoneal tissues of the upper abdomen.

The heart was negative except for slight atherosclerosis of the coronary arteries.

There was considerable atelectasis of all lobes of the lungs, particularly in the lower and posterior portions. The right upper lobe, in addition, was firm and had a slightly nodular consistency. On section, there was early peribronchial consolidation. The bronchi contained a moderate amount of mucopurulent, blood-tinged exudate.

The spleen was three times normal size. It was soft, and on section the pulp was easily scraped away. The secondary follicles were prominent.

A small laceration of the right lobe of the liver was not remarkable. Although local congestion and focal hepatic vein thromboses were noted adjacent to the missile track, the hepatic defect was partly filled by plasma clot.

The kidneys were moderately swollen and congested. On section, the cortex was slightly pale.

Gross anatomic diagnosis.—(1) Perforating shell-fragment wound of upper abdomen, with evisceration of transverse colon, small bowel, and omentum; multiple perforations of transverse colon; perforation of jejunum; perforation of second portion of duodenum; moderately severe laceration of liver; (2) generalized severe fibrinopurulent peritonitis; (3) generalized severe congestion, edema, and atelectasis of lungs; (4) early acute bronchopneumonia of right upper lobe; (5) acute splenomegaly, secondary to peritonitis and possibly to multiple transfusions; and (6) moderately severe passive congestion of kidneys.

Comment.—Death in this case appears to have been caused by severe visceral trauma and the effects of massive contamination of the peritoneal cavity. The chill which occurred during transfusion was attributed either to chilling of the patient or to the presence of pyrogens in the transfusion equipment. It was not thought to be due to incompatibility of the blood. The appearance of the urine, however, suggested that hemoglobin-derived pigment might have been present. Plasma was given in an unusually large volume during operation, in an effort to limit the amount of blood needed, and thus to lessen the danger of a transfusion reaction.

Microscopic observations.—The heart was negative, except for slight atherosclerotic changes in the coronary arteries.

The pulmonary tissue showed an extensive bronchopneumonia, confluent in places. The bronchial and alveolar exudate in some lobules was composed of polymorphonuclear leukocytes. In some areas, many red blood cells were mixed with the leukocytes. In one section in which the alveoli contained protein-rich edema fluid, a few hyalin membranes were seen in the respiratory bronchioles.

Sections from the liver showed large areas of hemorrhage and traumatic infarction. One section showed a moderate degree of vacuolation of the liver cells in all parts of the lobule.

Groups of fat cells were seen in some of the malpighian bodies of the spleen. Considerable nuclear debris was enmeshed in a fibrinous exudate which covered the capsule.

Sections from the kidneys showed that a moderate number of collecting tubules and a small number of distal convoluted tubules contained pigmented casts. Some of the proximal nephrons were dilated. There was no epithelial proliferation, interstitial edema, or inflammatory reaction.

Microscopic diagnosis.—Moderately severe hemoglobinuric nephropathy.

Comment.—This case represents another instance of hemoglobinuric nephropathy in a patient supposedly belonging to blood group O. In the experience of the 6713th Blood Transfusion Unit at Naples, which covered many thousands of donors, listings of the blood type on the identification tag were found to be incorrect in about 10 percent of the soldiers, and one wonders whether that happened in this case. Unless hemolyzed blood is injected, there would seem no reason for a transfusion reaction in a group O recipient when O blood is given. In crossmatching, there is one possible source of error in reading the result if the possibility is not borne in mind. Agglutination hemolysis may occur, and crossmatching may be reported by an unwary observer as compatible. (J. G. R.)

SUMMARY

This patient had a very severe abdominal wound, with massive evisceration of abdominal viscera, and death occurred within a relatively short time after injury. The blood pressure remained at a low level during operation and most of the postoperative period. It is thought that the most important lethal factors were (1) severe abdominal injury with evisceration and consequent peritonitis, (2) prolonged anesthesia and operation, and (3) bronchopneumonia and pulmonary edema.

Uremia per se probably was not important in producing death so soon after operation, and the importance of the renal lesion as a lethal factor is minimized by at least two facts, namely, the moderate renal changes present and the fact that the patient excreted 300 cc. of urine during a period of 48 hours in which the blood pressure ranged from 90/60 mm. Hg downward.

It was customary in World War II to disregard the blood group listed on the identification tag, for the reasons already stated. This patient was regrouped in the field hospital, and his blood type was found to be O. He did, however, receive blood which had been drawn 6 to 9 days earlier, and small amounts of free hemoglobin may have been present in the 3,500 cc. of blood which he received.

Case 12

CLINICAL DATA

This patient received a shell-fragment wound of the right hip and sacral region 9 October 1944, at about 0800 hours. He was brought into the field hospital at 1700 hours with a rapid, weak pulse and blood pressure of 70/50 mm. Hg. He had received 500 cc. of plasma. Before operation he received

another 500 cc. of plasma and 2,500 cc. of group O (his blood group) blood, but the blood pressure never rose above 90/60 mm. Hg. Through error, he did not receive penicillin before operation.

Operation was unavoidably delayed until approximately 24 hours after injury. Exploration revealed an extensive perforating wound of the right buttock with widespread destruction of the gluteal muscles and fractures of the right wing of the ilium and the right side of the sacrum. The missile track was filled with semiliquid, necrotic muscle, which was pale pinkish gray. The necrosis evident along the walls of the missile track seemed to extend for a considerable distance into the muscles of the lumbar region and posterior upper thigh. So extensive was the process that complete excision of damaged muscles was impossible. At operation, sections were taken from the right gluteus medius at the base of the wound and were fixed for microscopic study. At no time during operation were gas bubbles or crepitus noted in the muscle or in the subcutaneous tissue adjacent to the wound.

Laparotomy revealed two small perforations of the terminal ileum, but the site of entry of the foreign body could not be identified. The right colon was intact. Small spicules of bone had been driven into the soft tissue, and these fragments may have been responsible for the injury to the small bowel. Sigmoid colostomy was performed. No perforations were found on careful examination of the intraperitoneal portion of the rectum. Before the abdomen was closed, 10 gm. of sulfanilamide crystals were placed in the abdominal cavity. The wound of the hip was widely debrided, and a fasciotomy was performed along the right lateral gluteal fold. Zinc peroxide, which was sprinkled liberally throughout the gluteal wound, could not be activated because no reliable source of heat was available. Operation was completed at about 1200 hours 10 October. During its course, the patient received 1,000 cc. of blood.

Immediately after operation, the patient was given 2.5 gm. of sulfadiazine sodium by vein. On the third day, it was found that the penicillin which had been ordered intramuscularly in dosages of 25,000 units every 3 hours was being given subcutaneously. As soon as the error was discovered, 100,000 units were given intravenously.

For the first day or two after operation, the patient looked remarkably well. There was little systemic evidence of severe infection, the pulse remained within the normal range, and the maximum temperature elevation was 99.6° F. On the second postoperative day, the blood pressure was 126/90 mm. Hg. The patient appeared slightly drowsy and was oliguric. An attempt was made to render the urine alkaline by placing 4 gm. of sodium bicarbonate in the stomach every 2 hours. An intravenous infusion of 1,000 cc. of 1.25 percent sodium bicarbonate solution also was given daily. Although the total daily fluid intake averaged 3,000 cc., the greatest single volume of urine was about 100 cc., and the total output from operation to death, which occurred on the sixth day after wounding, was about 400 cc. The urine was dark amber brown and contained many granular casts and many erythrocytes. A few

sulfadiazine crystals were noted soon after operation. The hemoglobin by the copper sulfate method was 12.7 gm. percent and the plasma protein 5.1 gm. percent.

The patient received an average of 250 cc. of plasma daily, and during the immediate postoperative period he also received 750 cc. of carefully cross-matched O-type blood.

On 13 October, the blood pressure was 178/120 mm. Hg, but it declined from this level and during the last 3 days of life was in the range 140/80 to 160/85 mm. Hg. On 13 October, the leukocyte count was 6,000 per cubic millimeter, with a moderate increase in stab forms. There was also moderate pitting edema, and the temperature reached 100.2° F. On the night of the fifth postoperative day, moist rales were noted throughout the chest, and intra-tracheal aspiration was performed. The patient died the following morning, 15 October 1944, at 0800 hours, approximately 144 hours after injury.

AUTOPSY

Autopsy was performed an hour after death (Lunéville, France).

Gross observations.—Externally the body showed moderate pitting edema over the back and sacrum. There was no icterus.

The peritoneal, pleural, and pericardial cavities were negative.

The right side of the heart was greatly distended by blood; the tricuspid valve measured 15 cm. There was a considerable degree of atherosclerosis of the coronary arteries, most marked in the right circumflex artery.

There was complete atelectasis of all lobes of the lungs except the right upper lobe. There was loss of crepitus, and the involved lobes were rubbery in consistency. Consolidation was thought to be present but was difficult to detect because of the marked degree of atelectasis. On section, the lung was purple and beefy red. There was only a moderate increase in the amount of serous fluid which oozed from the cut surface. The bronchi contained a large quantity of hemorrhagic purulent exudate.

The spleen was twice normal size and moderately firm. On section, it did not seem remarkable, but the purple-red pulp scraped away somewhat more easily than would have been expected from the firmness of its consistency.

The liver was moderately enlarged. On section it was not remarkable except for the presence of scattered pinpoint areas of hemorrhage.

The gastrointestinal tract showed the operative changes already mentioned.

Both kidneys were considerably swollen, particularly in the anteroposterior diameter. Their size was estimated at 1½ times normal. The subcapsular surface was uniformly homogeneous, yellow gray, and of an opaque, slightly granular appearance. On section, the parenchyma bulged above the edge of the capsule. The cortex appeared somewhat thickened and was of the same yellow gray as the surface. The pyramids were gray brown; near their bases the tissue had an opaque granularity like that of the cortex. The tips of the pyramids were congested and the mucosa was hemorrhagic, as was the mucosa of the renal pelves generally. The renal arteries showed early atherosclerosis.

Examination of the adrenals showed liquefaction and destruction entirely out of proportion to the brief time which had elapsed since death. There was no evidence of medullary hemorrhage.

There was moderate edema of the bladder mucosa.

In the lumbosacral area was an extensive phagedenic wound track extending from the right posterolateral rib margin downward and across the midline to the left gluteal region. There was considerable undermining of the subcutaneous tissue, with involvement of the adjacent muscle and connective tissue about the periphery of the track. The odor was foul. The exudate was watery and grayish green, except that in many places it was slightly pink, the color suggesting the presence of blood or muscle pigment. The exposed sacrum and the wing of the ilium formed the floor of the wound. There was no evidence that the peritoneal cavity had been invaded.

At operation, an attempt had been made to provide drainage for the wound by making incisions along the right gluteal fold and in the posterior right flank. The edges of these incisions had the appearance of those of the original wound. Infection had extended upward to the level of the 12th rib along the lumbar muscles and downward into the posterior muscles of the upper thigh. Grossly there was no apparent predilection for muscle tissue, and adipose and connective tissue were extensively involved. In the midst of the wound, however, pale-pink, edematous, and necrotic muscle fibers were present.

Gross anatomic diagnosis.—(1) Perforating shell-fragment wound of right lumbosacral and gluteal regions, with extensive destruction of soft tissue, and compound, comminuted, incomplete fracture of right ilium; compound, comminuted, incomplete fracture of right posterior aspect of sacrum; two healing perforations of terminal ileum; (2) extensive phagedenic infection of wound of gluteal region, with necrosis of muscle and connective tissue, bacterial cause unidentified; (3) nephrosis, possibly hemoglobinuric in type, with pulmonary congestion and edema, moderately severe, manifest clinically by oliguria, uremia, and arterial hypertension, moderately severe; (4) purulent bronchitis, bilateral, severe, with complete atelectasis of left lung, right lower and middle lobes, due to bronchial obstruction by exudate; (5) extensive bilateral necrosis of adrenal medulla, possibly due to overwhelming infection; and (6) moderate, generalized atherosclerosis.

Comment.—The clinical and gross post mortem findings in this case are typical of pigment nephrosis. In view of the widespread destruction of skeletal muscle, myoglobin rather than hemoglobin may have been the offending pigment. Whatever the pigment, the kidney always appears to be particularly vulnerable to it during periods of severe shock.

This type of infection is of considerable interest. Bubbles of gas were never observed, but the invasive and destructive properties of the infecting organisms were evidently very great. A mixed infection which includes microaerophilic streptococci deserves consideration. The delay in effective penicillin therapy may or may not be important. The delay of 24 hours in operation certainly was.

Microscopic observations.—Sections of the lungs showed small patches of atelectasis. Several lobules were filled with exudate composed largely of red blood cells, stringy protein deposits, and small numbers of polymorphonuclear leukocytes and mononuclear cells. The character of the alveolar exudate varied in different lobules. In some it was chiefly composed of erythrocytes. In others, the red blood cells were mixed with granular, pink-staining protein precipitate. In still others, there was an admixture of these elements with mononuclear cells. A few small bronchi contained polymorphonuclear leukocytic exudate. Slight edema of the interlobular septa and blood were observed in scattered alveoli, but nothing else of note was seen. On frozen section, fat emboli, in moderate numbers, were present in capillaries in the alveolar septa.

The liver cords in the centers of the lobules were atrophic. The cells contained fat vacuoles and granular brown pigment. A few foci composed of histiocytes were seen. The portal triads were infiltrated with moderate numbers of lymphocytes.

The splenic pulp was moderately congested. There was a large amount of formalin-pigment (formaldehyde pigment) precipitate.

A large number of distal convoluted and collecting tubules in the kidneys were plugged with pigmented casts. The proximal nephrons were slightly dilated. Some tubules contained epithelial debris mixed with pigment. There was a moderate degree of epithelial proliferation, most evident in the medulla, with the formation of a few granulomas in the interstitial tissues. Only a very slight inflammatory reaction, consisting of lymphocytes, was seen. A small number of sulfonamide crystals were identified in the tubules.

The appearance of the voluntary muscle varied in different sections, and even in different parts of the same section. Many muscle fibers were swollen. Some took an orange stain. Others had lost striations and nuclei. In places, the interstitial tissues were edematous. There was a large amount of polymorphonuclear leukocytic infiltration in the interstitial tissues in some areas and a small amount in others. In still others, there was an absence of inflammatory reaction. A few vessels were thrombosed.

Sections examined after straining by the MacCallum-Goodpasture technique showed large numbers of organisms, usually mixed. There were present large, fat, gram-positive bacilli, some of which were comma shaped. No spores were seen. The other prominent organism was a gram-positive coccus. Some of these cocci were small, some large.

Microscopic diagnosis.—Moderate pulmonary fat embolism.

Comment.—Histologically the voluntary muscle lesion in this case appears to be a combination of clostridial and suppurative myositis. Without cultural proof, an exact diagnosis is not possible. One can guess, however, that the gram-positive rods were *Clostridium sordellii* and that the cocci were streptococci.

The renal lesion is typical of hemoglobinuric nephropathy. The very destructive muscle lesion might conceivably have liberated myoglobin, but whether this would be absorbed and then excreted through the kidney, as in the crush syndrome, it is not possible to say. In addition, clostridial organ-

isms are hemolytic, and, if hemolysis were sufficiently severe, this process, too, might produce hemoglobinemia and hemoglobinuria. In a recipient belonging to group O and receiving only group O blood, there would seem no reason for a transfusion reaction, unless hemolyzed blood had been injected. This fact would tend to favor a relationship between the myositis and the nephropathy.

SUMMARY

This case provides another example of posttraumatic renal failure and pigment nephrosis. The type of wound infection encountered here, however, was not common, and the myositis per se may have been important in the development of the renal lesion. In attempting to assess the role of this infection in the pathogenesis of the nephrosis, other factors should not be overlooked, including prolonged and severe shock due to trauma and hemorrhage, massive transfusion therapy, and sulfonamide administration. Probably the single most important lethal factor was the prolonged period of shock, and it may well be in this regard that the myositis exerted its deleterious effect upon the kidney.

Case 13

CLINICAL DATA

This patient suffered a shell-fragment wound of the right costovertebral region 18 May 1944 at 1300 hours. After a delay of 38 hours, during which he received 1,000 cc. of plasma and several injections of morphine, he arrived at a field hospital 20 May at 0300 hours. The delay in evacuation was due to an offensive breakthrough; combat units outstripped supporting medical units.

At this time, the patient's condition was critical. The blood pressure was 88/52 mm. Hg, the pulse 98, and the respiration 26. He was dehydrated, febrile, and semistuporous. In 4 hours after he reached the field hospital, he received 1,400 cc. of plasma and 1,000 cc. of group O whole blood; 10,000 units of polyvalent gas-bacillus antitoxin; and 100,000 units of penicillin by vein and 100,000 units by instillation into the right pleural cavity, from which 1,000 cc. of bloody, foul-smelling fluid had been aspirated. These measures produced little improvement; at 0600 hours the blood pressure was 108/30.

At operation, a laceration of the diaphragm was closed. The chest was also closed after a catheter had been inserted in the right pleural cavity. Laparotomy revealed a laceration of the right kidney. The kidney was not removed, and drainage was provided for the perirenal, subdiaphragmatic, and subhepatic regions on the right. The patient was apparently in fairly good condition throughout the procedure but died suddenly as operation was being concluded.

AUTOPSY

The autopsy was performed 1 hour after death (Minturno, Italy).

Gross observations.—The skin and sclerae were definitely icteric. The abdomen was moderately distended and tympanitic. No bubbles of gas were

noted in the tissues at the site of entrance of the missile, which was beneath the 12th rib in the right costovertebral region. The shell fragment had passed forward through the reflection of the diaphragm and then through the dome of the liver, coming to lie beneath the skin in the right midclavicular line at the level of the sixth intercostal space.

The right pleural cavity was remarkable in that the right lung was almost completely collapsed and the entire cavity was lined with a thick, fibrinous exudate. This cavity contained about 200 cc. of bloody fluid. The stomach was greatly dilated; it extended downward to a point 3 cm. below the umbilicus. It was so distended with gas that it appeared tense and drumlike. The hepatic flexure of the colon was plastered to the anterior surface of the right kidney by fibrinous exudate. There was moderate bile staining of the lesser peritoneal sac and of the retroperitoneal tissues of the right renal region.

There was practically total collapse of the right lung, which was bound down by the exudate just described. This exudate covered all exposed surfaces, and in the thicker portions, which lay posteriorly, there were many bubbles of gas. The amount of gas present was out of proportion to the degree of subcutaneous emphysema present, and it was thought that the gas represented the product of bacterial growth in the exudate. This lung contained practically no air, and on section it was found to be almost completely consolidated, the collapsed tissue being suffused with hemorrhagic fluid. There was almost complete atelectasis of the left lower lobe and moderately severe patchy atelectasis of the left upper lobe, in which peripheral emphysematous blebs were observed. The bronchi contained moderate amounts of serous bloody fluid, but there was no evidence of obstruction of a major bronchus.

A missile had passed through the dome of the right lobe of the liver. Incision through Glisson's capsule at a point of hemorrhagic discoloration released bloody fluid containing bubbles of gas. On section, the wound track measured 5 to 6 cm. in diameter. The walls were made up of pale-yellow, opaque, necrotic liver parenchyma, which contained small, irregular bubbles of gas and had the appearance of fermented culture media. Bubbles of gas were expelled from the blood vessels of the liver.

Except for the extreme gastric dilatation already described, and thinning of the wall by pressure of retained air and gas, the stomach was not remarkable.

The passing missile had caused a severe contusion of the central portion of the right kidney, and on section a spherical hemorrhagic area was seen, which was 4 to 5 cm. in diameter. Overlying this area was considerable capsular reaction, but the cortex of the kidney did not appear to be directly lacerated by the missile.

The spleen was moderately swollen and somewhat softer than normal.

The capsule overlying the relatively normal portion of the kidney stripped away with some difficulty and slight tearing of the underlying parenchyma. The renal pelvis on the right was bile stained to a degree not noted on the left.

Gross anatomic diagnosis.—(1) Shell-fragment wound of right thoraco-abdominal region, with right hemopneumothorax and extreme atelectasis of

right lung; empyema of right pleural cavity, possibly caused by clostridia; laceration of right lobe of liver with extensive necrosis due to anaerobic infection; and (2) severe atelectasis of left lower lobe and partial atelectasis of left upper lobe, secondary to right pneumothorax and gastric dilatation; severe acute dilatation of stomach; severe contusion of right kidney, and moderately severe contusion of hepatic flexure of colon; sutured laceration of right diaphragm.

Comment.—When this patient was received in the field hospital, he was suffering from overwhelming infection and severe respiratory embarrassment. Gastric dilatation and atelectasis of the left lung may have accounted for his sudden death on the operating table. A roentgenogram taken before operation showed a large gas bubble in the region of the stomach.

Microscopic observations.—The heart veins were dilated and engorged with blood.

Two sections of the lungs showed massive collapse with patent bronchi. Many dust cells were present. The pleural surfaces were covered with a fibrinopurulent exudate which showed no evidence of organization. Exudate stained with the MacCallum-Goodpasture stain showed many gram-positive spore-bearing bacilli morphologically consistent with clostridia.

One section of the liver showed extensive traumatic necrosis. A second showed central congestion, acidophilia, and slight vacuolation.

The splenic pulp was very cellular.

One section of kidney tissue showed only moderate diffuse dilatation of all portions of the nephrons. A second showed massive hemorrhagic traumatic necrosis. Many of the collecting tubules were plugged with casts; some were hyaline, some consisted solely of red blood cells, and others showed all grades of transition.

The pleural surface of the pericardium was covered with a fibrinopurulent exudate. The pericardial surface was normal.

Comment.—This is the first case to come to autopsy in the Naples laboratory with what appears to be a clostridial infection of the pleural cavity. (T. B. M.)

SUMMARY

Even if this patient had survived operation, it is doubtful that he could have tolerated such overwhelming infection. His response to replacement therapy before operation was slow and incomplete and was in itself indicative of the profound circulatory changes which characterize clinical gas-bacillus infection.

Case 14

CLINICAL DATA

This patient received a bullet wound of the mid-upper abdomen 17 April 1945, at 1800 hours. He reached a field hospital 18 April, at 0130 hours, without replacement therapy during evacuation. The blood pressure at this

time was 80/60 mm. Hg and the pulse 120. Improvement was prompt after the administration of 500 cc. of plasma and 500 cc. of whole blood, and the blood pressure before operation was 128/80 mm. Hg. The patient's blood belonged to group O.

Laparotomy through a left paramedian incision revealed the omentum to be badly lacerated and torn. The proximal jejunum, which was transected, was repaired by end-to-end anastomosis. The splenic flexure of the colon, which was badly lacerated, was resected and the loops were brought out in the left abdomen as a colostomy. The posterior wound of exit in the left flank was debrided. Exploration showed that the left kidney was lacerated, but it was not removed. The perirenal space was drained, and drains were brought out through the inferior portion of the abdominal incision. The patient's condition was satisfactory during operation, in the course of which he received an additional 500 cc. of blood.

His condition the day of operation continued fairly good. He voided 600 cc. of urine. The following day, 19 April, his status worsened rapidly; he became stuporous and was unable to void. The following laboratory values were reported: Hematocrit, 51; hemoglobin, 17.2 gm. percent; and plasma protein, 6.5 gm. percent.

On 21 April, the patient's condition was fair, though drainage of small-bowel contents was noted through the posterior wound in the left flank, and it was thought that the jejunal anastomosis might have broken down.

On 22 April, the patient was very ill, and there was evidence of a severe peritonitis. He died on this day at 1000 hours, approximately 112 hours after injury.

AUTOPSY

Autopsy was performed 4 hours after death (Poxdorf, Germany).

Gross observations.—Externally the body showed dehydration and moderate weight loss. The abdomen was quite distended. Foul-smelling, watery fluid oozed from the wound in the left flank.

A considerable quantity of gas escaped when the abdominal cavity was opened. The cavity contained about 2,000 cc. of foul, blood-tinged fluid in a large pocket which extended from the left upper abdomen across the midline to the right para-umbilical region. The walls of this pocket were made up of fibrinopurulent exudate, and the serosa of the adjacent bowel was opaque and dark in color. Fluid present in the pelvic portion of the peritoneum contained small particles of undigested food. Strands of purulent exudate were scattered throughout the peritoneal cavity. The diaphragm was elevated to the level of the third rib bilaterally; both leaves were intact.

There was much old blood in the left perirenal tissues.

The left cardiac ventricle showed moderately severe concentric hypertrophy.

The lungs revealed only slight congestion and atelectasis of the inferior portions of the lower lobes.

The spleen was somewhat softer than normal.

In the posterior wall of the stomach were two unclosed perforations. The larger, which measured 4 cm. in diameter, lay near the attachment of the gastrotocolic omentum in the midportion of the greater curvature. The second, which measured 1 cm. in diameter, overlay the tip of the pancreas. The stomach was empty and contained no blood, but apparently considerable bleeding had taken place into the peritoneal cavity from the gastric perforations. The jejunojejunostomy was not remarkable.

There was a small area of trauma at the extreme tip of the tail of the pancreas. Two small foci of fat necrosis were present in the interlobular adipose tissue of the pancreas. There was no gross evidence that pancreatic juices had entered the peritoneal cavity to any appreciable extent.

On the anterolateral aspect of the lower pole of the left kidney was a 3-cm. stellate laceration.

Gross anatomic diagnosis.—(1) Perforating bullet wound of abdomen, with transection of proximal jejunum, healing jejunostomy; severe laceration of transverse colon, colostomy; two large perforations of posterior wall of stomach; moderately severe laceration of left kidney, with retroperitoneal hemorrhage; minimal laceration of tail of pancreas; (2) severe, acute, generalized peritonitis, secondary to unclosed perforations of stomach; and (3) gastric fistula via wound of exit in posterior left flank, secondary to unclosed gastric perforations.

Comment.—The technical error of omission in this case emphasizes the necessity for thorough exploration of the abdomen in any combat-incurred wound. Unfortunately, the lesser peritoneal sac was not explored at operation.

Microscopic observations.—On the pleural surface of the lung, an exudate of polymorphonuclear leukocytes, blood, and fibrinoid material was noted. The alveolar walls were approximated, and blood or a slight amount of eosinophilic coagulum was present in some alveoli. The vessels were engorged. Alveolar hemorrhage was most apparent subpleurally. A second section showed approximation of the alveolar walls with foci of intra-alveolar fibrinoid material and clumps of polymorphonuclear leukocytes; these changes were moderately extensive in certain areas. Several small bronchioles showed ulceration of the epithelium with blood and polymorphonuclear leukocytes in the lumens. Other bronchioles were partly filled by accumulations of polymorphonuclear leukocytes.

A fibrinoid material with intermingled polymorphonuclear leukocytes was present on the capsular surface of the spleen. The sinusoids were large and filled with blood.

There was vacuolation of the liver cells, chiefly about the central vein of the lobule. The veins appeared to be slightly dilated.

Hemorrhage had occurred into the interlobular fat of the pancreas, and there was a focal collection of fibrinoid material with enmeshed leukocytes.

On the serosal surface of the stomach was an extensive fibrinoid exudate with scattered polymorphonuclear leukocytes. At the attachment adjacent to the serosa, the exudate showed early organization, as evidenced by fibroblastic and capillary proliferation.

The tubules of the kidney showed degeneration to the point of necrosis, with granularity of the cytoplasm and loss of nuclear detail. The glomeruli were small. Another section showed irregular necrosis and hemorrhage into the parenchyma. About the periphery of these areas were moderate accumulations of polymorphonuclear leukocytes.

Microscopic diagnosis.—(1) Moderate lobular pneumonia; (2) fibrinopurulent pleuritis; (3) severe traumatic renal necrosis and hemorrhage; (4) slight fatty metamorphosis of liver; (5) moderate interlobular pancreatic hemorrhage; and (6) pulmonary atelectasis.

Comment.—The microscopic findings were in essential agreement with the gross diagnosis. The peritonitis was well illustrated by the exudate seen on the capsular surface of the spleen and the serosal surfaces of the stomach and pancreas. (E. N. B.)

SUMMARY

This case is an example of one of the numerous pitfalls which can occur as the result of failure to carefully explore all abdominal wounds. In spite of the severity of the abdominal wound, the patient tolerated operation surprisingly well. Failure to close two perforations of the stomach, however, led to death on the fourth postoperative day.

Case 15

CLINICAL DATA

This patient sustained a shell-fragment wound of the right lumbar region 1 June 1944, at 1510 hours. He reached a field hospital at 1800 hours, after having received 1,000 cc. of plasma. The blood pressure at this time was 86/44 mm. Hg and the pulse 120. Remarkable improvement occurred after the administration of 1,000 cc. of plasma and 500 cc. of whole blood. Just before operation, the blood pressure was 120/88 mm. Hg, and there was no excessive bleeding from the large wound.

At operation, the wound of the right lumbar region was found to be perforating and very large. The missile had entered the abdomen just to the right of the third lumbar vertebra and had caused extensive destruction of the body of this vertebra and of the cauda equina. There was a massive defect in the lumbar muscles on the right, with extreme damage to the cecum, which required resection. An ileotransverse colostomy was performed. The wound was debrided and drained, and a large pack was placed in the retroperitoneal muscle defect. During operation, in spite of continued transfusion of whole blood, the patient's condition became critical. He did not rally after operation and died 2 June 1944.

AUTOPSY

Autopsy was performed 4 hours after death (Cori, Italy).

Gross observations.—There was no apparent invasive infection of the large lumbar wound, which measured 6.0 by 8.0 cm. and which made a gaping defect in the right paravertebral region. The floor of this defect was formed by the posterior portion of the parietal peritoneum. A large retroperitoneal hematoma was present.

The pericardial and pleural cavities were not remarkable. There was no increased fluid in the peritoneal cavity, although the loops of small bowel were loosely bound together by strands of fibrinopurulent exudate.

The heart showed minimal coronary atherosclerosis, with some increased thickness of the left ventricular myocardium.

The lungs showed only moderate congestion and edema of both lower lobes.

The liver, spleen, and adrenal glands were essentially negative. The gastrointestinal tract showed only a recent healing ileotransverse colostomy.

The kidneys were normal, and the intact right ureter bridged the lumbar defect. There was moderate hydroureter and slight hydronephrotic dilatation of the right renal pelvis. The orifice of the ureter was partly occluded by two blood clots at the level of the wound (third lumbar vertebra). No blood was present in the renal pelvis. The bladder showed somewhat increased trabeculations of the mucosal surface.

Examination of the vertebral column showed extensive destruction of the third lumbar vertebra, with contusion of the filaments of the cauda equina.

Gross anatomic diagnosis.—(1) Severe shell-fragment wound of right posterior abdomen, with multiple lacerations and perforations of cecum and ascending colon, secondary resection of cecum and ileotransverse colostomy; compound comminuted fracture of body and transverse and spinous processes of third lumbar vertebra, with severe retroperitoneal hemorrhage; moderately severe contusion of right ureter, with moderate hemorrhage into ureter and slight secondary hydronephrosis; (2) severe, acute, purulent, generalized, early peritonitis, secondary to wounds of cecum and ascending colon; and (3) severe, multiple contusions and lacerations of cauda equina, secondary to fracture of third lumbar vertebra.

Comment.—The massive trauma, blood loss, and severe peritoneal contamination made the outlook in this case very poor from the first. It is surprising that the patient responded as well as he did to 1,000 cc. of plasma and only 500 cc. of blood. In retrospect, it seems probable that he received too much plasma, and, more important, too little blood before operation.

Microscopic observations.—The lungs showed diffuse partial atelectasis and marked congestion. A few fat droplets were present in the arterial tree, chiefly in the arterioles.

The kidney showed a focus of interstitial and intratubular hemorrhage consistent with a traumatic lesion. Scattered through the cortex were spaces lined with very flat epithelium or swollen endothelium which contained orange-

staining material. No pigment precipitates were found in any part of the tissues which could be recognized definitely as a nephron. The nature of the lesion was not apparent, but it was not regarded as important to clinicopathologic correlation.

Microscopic diagnosis.—Minimal pulmonary fat embolism. (T. B. M.)

SUMMARY

It is remarkable, in retrospect, that this patient lived as long as he did, because of (1) extreme tissue destruction and consequent loss of blood, (2) the difficulty of controlling blood loss during operation, and (3) the overwhelming contamination of the peritoneal cavity. Early postoperative deaths were not uncommonly seen in severely wounded patients after such a long and tedious operation as this patient underwent.

CHAPTER X

Traumatic Evisceration (312 Casualties)

Samuel B. Childs, M. D.

In the 3,154 instances of abdominal injury observed by the 2d Auxiliary Surgical Group during 1944 and 1945, there were 312 traumatic eviscerations (table 19), 126 of which (40.4 percent) were fatal. Evisceration, for the purposes of this discussion, is defined as the protrusion of an abdominal viscus outside of the peritoneal cavity through a missile track which has interrupted the continuity of all layers of the abdominal wall.

TABLE 19.—*Distribution of wounds and deaths in 312 traumatic eviscerations in 3,154 abdominal injuries*

Organs injured	Cases	Proportion Percent	Deaths	Case fatal- ity rate
Omentum only.....	86	27.57	32	37.2
Stomach.....	9	2.88	3	33.3
Stomach, small bowel, and colon.....	5	1.60	2	40.0
Stomach and colon.....	2	.64	2	100.0
Stomach and spleen.....	1	.32	0	0
Small bowel.....	123	39.43	43	34.9
Small bowel and colon.....	24	7.69	14	58.3
Small bowel and liver.....	1	.32	0	0
Colon.....	38	12.19	21	55.3
Colon and liver.....	3	.96	3	100.0
Colon and spleen.....	1	.32	0	0
Liver.....	7	2.24	3	42.8
Spleen.....	3	.96	0	0
Not recorded.....	9	2.88	3	33.3
Total.....	312	100.00	126	40.4

In this series, the frequency of evisceration of a particular organ apparently varied in relation to (1) its own mobility and volume and (2) the site and size of the missile track. The omentum alone, the small bowel alone, the colon alone, and the small bowel and colon in combination were involved in 86.9 percent of the total number of eviscerations. In 5 injuries (4 involving the small bowel and 1 the small bowel and colon), the protruding abdominal viscus had not been injured. The organ extruded was not recorded in 9 cases.

Exclusive of 25 cases in which the site of extrusion was not recorded and of 86 in which only the omentum was involved, the evisceration occurred in the upper abdomen 75 times, in the lower abdomen 68 times, in the left flank 28 times, the right flank 13 times, the left chest 10 times, the right chest 3 times, the right side of the back twice, and the left sacral region and the left buttock

in 1 case each. If the wound of entry in perforating wounds was sufficiently large, evisceration sometimes occurred through it. More often it occurred through the wound of exit. Sometimes a wide-open track was found between the wounds of entry and exit.

The wounding agent, which was recorded in 299 cases, was a shell fragment in 171 cases, a small-arms bullet in 97, and a mortar, bomb, grenade, or mine fragment in the remaining 31 cases.

CASE FATALITY RATE IN RELATION TO SHOCK AND PERITONITIS

In 86 cases, 32 of which (37.2 percent) were fatal, only the omentum protruded from the abdomen. The 24 deaths which occurred in this group by the end of the second postoperative day were all attributed to shock. Two deaths in this group (6.3 percent of the total number) which occurred on the ninth postoperative day were attributed to peritonitis; perforations of the stomach and the colon were also present in both. Four patients in this group died of other causes, and in two instances (also 6.3 percent of the total number) the cause of death was not recorded. The proportion of the 32 deaths attributed to peritonitis (6.3 percent), corrected for the 2 no-record cases to 6.7 percent, did not exceed the case fatality rate for peritonitis (12.3 percent) in the whole group of 3,154 cases (p. 208). The data suggest that evisceration of the omentum alone introduced no additional factor of contamination and was significant only in relation to the severity of the abdominal wound.

In the 226 cases in which an abdominal organ other than the omentum was extruded, there were 94 deaths (41.6 percent). All but 2 of the 61 deaths which occurred by the end of the second postoperative day were caused by shock (table 20). The 10 deaths caused by peritonitis accounted for 10.6 percent of the 94 fatalities, corrected for no-record cases to 11.6 percent. This rate approximated the case fatality rate for peritonitis (12.3 percent) in the whole group of 3,154 cases.

The single fatality in the 5 cases in which there was no injury to the extruded viscus (in all instances intestine) occurred on the fourth postoperative day and was caused by a massive pulmonary embolism. Whether evisceration occurred in this group of casualties at the time of wounding or subsequently was not known. It seems significant, however, that, whatever the duration might be, none of these 5 patients exhibited signs of clinical shock either when they arrived at the field hospital or during their later postoperative course.

CASE FATALITY RATE IN RELATION TO MULTIPLICITY FACTOR AND TIMELAG

An analysis of the 298 cases in which sufficient data were available for this purpose (1) indicated that the multiplicity factor played the same significant role in the case fatality rate for traumatic eviscerations as for other groups of injuries (table 21), and (2) further supported the concept that this

TABLE 20.—Primary cause of death and time of death in 94 traumatic eviscerations ¹

Cause	Deaths	Proportion	Postoperative day									
			2d	3d	4th	5th	6th	7th	8th	9th	After 9th	Not recorded
		Percent										
Shock.....	59	62.8	59									
Peritonitis.....	10	10.6		2		1	1	1	2	1	2	
Anuria.....	5	5.3			3	1			1			
Pulmonary embolism.....	4	4.2			1	1	1		1			
Pneumonitis.....	3	4.2		1		2	{ 1 }					
Empyema.....	1											
Thrombosis, inferior mesenteric vein.....	1	1.1	1									
Brain injury.....	1	1.1	1									
Intestinal obstruction.....	1	1.1					1					
Jaundice, edema.....	1	1.1							1			
Not recorded.....	8	8.5		2	1	2					2	1
Total.....	94	100.0	61	5	5	7	3	2	5	1	4	1

¹ The 32 fatal cases in which only the omentum was extruded are excluded from this table.

factor is a satisfactory index of the severity of battle-incurred abdominal injuries.

The influence of the timelag is by no means as clear cut as is the influence of the multiplicity factor (table 22). Variations in the case fatality rate suggest that other factors played a part. Two are immediately apparent:

1. A large proportion of severely wounded men seen after a short timelag had wounds whose lethality was not altered by surgery.

2. Men who were more lightly wounded (relatively or absolutely) died after a longer timelag and in smaller numbers. Probably not all of the casualties with traumatic eviscerations would have died within a 10-day period if they had not been operated on, and certainly surgery could not alter the essentially lethal nature of the wounds sustained by many of the severely injured casualties.

TABLE 21.—Combined influence of evisceration and multiplicity factor on case fatality rates in 3,129 abdominal injuries

Organs injured	Without evisceration			With evisceration		
	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate
None.....	287	21	7.3	5	1	20.0
One.....	1,253	177	14.1	95	24	25.2
Two.....	913	247	27.1	101	38	37.7
Three.....	279	119	42.7	71	43	60.5
Four.....	81	48	59.3	15	11	73.3
Five.....	16	16	100.0	7	5	71.4
Six.....	2	2	100.0	4	4	100.0
Total.....	2,831	630	22.3	298	126	42.3

TABLE 22.—*Influence of timelag on case fatality rates in 203 traumatic eviscerations*

Timelag	Cases	Deaths	Case fatality rate
0 to 6 hours.....	77	29	37. 7
6 to 12 hours.....	94	42	44. 7
12 to 18 hours.....	16	5	31. 3
18 to 24 hours.....	6	2	33. 3
Over 24 hours.....	10	4	40. 0
Total.....	203	82	40. 4

In 41 of the 123 instances in which evisceration of the small bowel occurred, only the bowel was extruded, and there were no complicating multi-visceral injuries. The bowel itself was injured in all 41 cases, but the absence of the compounding effect of injuries to other structures makes it possible to consider in this group the effects of evisceration per se on the case fatality rate for abdominal injury.

There were 8 deaths, 19.5 percent, among these 41 patients. Four died within the first two postoperative days, in shock, with peritoneal contamination by small-bowel contents perhaps playing some part in the fatality. Two died of peritonitis, on the 8th and 22d days, respectively, after operation. Another died of pneumonia on the 5th day, and the remaining patient died on the same day, of an unstated cause. The timelag in all of these cases was short, the average being 5½ hours, which shows that it was not necessary to keep the patients in the shock ward for a long time before operation. It also implies priority of evacuation and surgery. In spite of these favorable factors, the case fatality rate in these 41 cases (19.5 percent) was higher than the rate of 13.1 percent for the 314 univisceral injuries of the small bowel in which evisceration did not occur.

This discrepancy suggests that traumatic evisceration is, in itself, a serious type of injury. This is well demonstrated by comparison of the case fatality rates in casualties who did and who did not sustain it. In the first five multiplicity categories (0 to 4 organs wounded), the average increase in rates from category to category when evisceration had occurred was approximately 13 percent (table 21). The trend was reversed when five organs were injured, but the figures are not large enough to be of statistical significance. Apparently evisceration affected the prognosis adversely to approximately the same degree as did the involvement of each additional organ in the multiplicity factor scale (table 21).

The occurrence of traumatic evisceration was also, in general, an indication of the severity of the wound. It was observed in only 1.7 percent of patients having no visceral injury but in 4 out of 6 with 6 viscera damaged (table 21).

CHAPTER XI

Diagnosis and Preoperative Routine

W. Philip Giddings, M. D., and Luther H. Wolff, M. D.

DIAGNOSIS

The preoperative diagnosis of visceral injuries in battle casualties was necessarily inexact. It was based chiefly on probabilities. It required careful consideration of (1) the site of the wound of entry, (2) the site of the wound of exit, (3) the direction from which the soldier believed he was struck, (4) his posture at the time of wounding, and (5) the position of the retained foreign body as demonstrated by roentgenologic or fluoroscopic examination.

Diagnosis was particularly difficult in multiple wounds of the abdominal wall, since any one, or several, of the fragments which had caused the visible injuries might have penetrated the peritoneal cavity. Exploration for diagnostic purposes was frequently necessary in injuries of this kind. It was also the established routine in any patient in whom the possibility of peritoneal or extraperitoneal visceral injury could not be positively excluded by any other method. In almost every instance of abdominal injury, a final and complete diagnosis was possible only after direct visualization of the peritoneal cavity at laparotomy.

It was always important to determine whether a hollow viscus had been injured, with resultant soiling of the peritoneum, because patients with this type of injury were given priority of treatment. As a rule, the location of the wound combined with unmistakable signs of established peritoneal irritation left no doubt that spillage had occurred, though in the occasional case diagnosis was not so simple. In the evaluation of doubtful cases, the absence of audible peristalsis was a useful diagnostic aid. On the other hand, peristalsis might be present if soiling were localized to the retroperitoneal space or to the lesser peritoneal cavity. Similarly, blood in the peritoneal cavity might give rise to peritoneal irritation, and blood in the urine, gastric contents, or feces was always important diagnostically; but its mere absence in these specimens did not necessarily exclude wounds of the urinary tract or of the stomach (pp. 255, 304). Rectal examination was an essential part of the diagnostic routine, and it was particularly important in wounds of the buttocks and upper thighs. Retroperitoneal injury, uncomplicated by other injuries, occasionally simulated peritonitis.

It was essential to remember, in the evaluation of symptoms and signs in casualties with abdominal wounds, that the clinical picture could be materially altered by the administration of morphine before the examination.

Thoracoabdominal wounds.—Experience showed that it was of the utmost importance to establish the presence or absence of an associated abdominal

injury in every thoracic wound (table 6). Wounds of the chest below the seventh interspace posteriorly and below the fourth rib anteriorly were regarded as possible thoracoabdominal wounds. The potentialities, however, were not limited to these areas. Perforation of the diaphragm was a possibility in any of the wounds caused by missiles which had entered anywhere from the gluteal region to the shoulder, though in most injuries of this kind the wound of entrance was in the lower half of the thorax. Among the 903 thoracoabdominal injuries treated in the period 1943-45 by the 2d Auxiliary Surgical Group, there were 66 (7.3 percent) in which the diaphragm was perforated from below.

Pain in the lower thorax was one of the reasons why the diagnosis of abdominal injuries which were associated with thoracic injuries was often difficult. It was sometimes helpful to reexamine the patient after intercostal nerve block; abdominal rigidity caused by peritonitis persisted after the block, while pain and muscle spasm arising from thoracic injury might be considerably reduced. If, however, too great reliance were placed upon these observations, the conclusions might be erroneous. Pain referred to the shoulder was found to be important evidence of injury to the diaphragm. Though pain was not always present in such cases, it was extremely infrequent in injuries limited to the thorax.

Roentgenologic studies, though often inadequate for practical reasons, were an invaluable aid in suspected thoracoabdominal injuries. Often, however, in spite of the information thus provided, abdominal exploration was regarded as mandatory. It was usually carried out through a thoracotomy incision.

PREOPERATIVE ROUTINE

The preoperative care of the casualty with an abdominal wound included the following measures: Placing the patient on a clean litter; removal of all his clothing; maintenance of body heat by blankets placed under as well as over him; securing a rapid clinical history; making of a rapid but complete physical examination; blood typing and crossmatching; catheterization, if the patient could not void voluntarily, and urinalysis; passage of a Levin tube, with gastric aspiration; and roentgenologic examination. As soon as possible, even before these studies were completed, measures of resuscitation were instituted and penicillin sodium (20,000 to 25,000 units) was administered by the intramuscular or intravenous route. Blood was always administered according to the indications of the special case (p. 124). Hematocrit and hemoglobin values were carefully checked.

Patients with thoracoabdominal injuries presented special problems in preoperative preparation because blood and mucus were likely to accumulate in the pharynx and throat. If they were conscious, they could frequently raise the accumulation by voluntary coughing. If coughing was painful, it could be facilitated by intercostal nerve block by the anesthetist. All unconscious patients, as well as some who were conscious, required tracheobronchial suction for the removal of secretions and improvement of the respiratory exchange.

The usual method was to pass through the nose a long #16 catheter, with a hole in the side near the proximal end and several holes in the distal end, and to suck out the material through it. If one application of the tube was not sufficient to clear the airway, it was reintroduced. Preoperative thoracentesis was also employed to improve the respiratory exchange in cases of pneumothorax or hemopneumothorax.

The measures described were usually carried out by the shock officer, assisted by the anesthetist (p. 120) and other personnel working under his direction. It was, however, the ultimate duty of the surgeon to assure himself that all the steps of the preoperative routine had been properly carried out. Ideally, the shock officer and the surgeon cared for the patient jointly; but if casualties were heavy, the surgeon was almost always occupied elsewhere, and the ideal was therefore not achieved. Nevertheless, regardless of circumstances, it was the surgeon's responsibility before operation to review the history, physical findings, laboratory data, and roentgenograms, and it was also his responsibility, preferably in consultation with the shock officer, to determine the optimum time for operation in every case.

CHAPTER XII

Anesthesia

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For the most part, anesthesia in the 3,154 abdominal injuries treated by the teams of the 2d Auxiliary Surgical Group during 1944 and 1945 was administered by physicians. Many of the 45 anesthetists attached to the group had received formal training. Others had had limited training and experience, but some had had neither training nor experience. Ideally, because soldiers with abdominal injuries may present incredible difficulties in anesthetic management, anesthetists who care for them should possess a good general medical background, an understanding of the principles of management of the physiologic disturbances following abdominal and thoracoabdominal wounds, and proficiency in the diagnosis and treatment of shock and in the recognition and care of complications. For obvious reasons, this ideal was frequently not achieved.

STATUS OF CASUALTIES

Detailed information concerning the status of casualties on their arrival at the field hospital after triage at the division clearing station is set forth elsewhere (p. 124), but certain of these facts should be reiterated here; they furnish the background for the discussion of anesthesia in abdominal injuries in wartime.

The majority (approximately 90 percent) of the casualties with abdominal wounds treated in the field hospitals by surgeons of the 2d Auxiliary Surgical Group were nontransportable; that is, they required immediate operation. The timelag from wounding until hospitalization ranged from between 15 and 30 minutes to between 30 and 40 hours. Exclusive of the cases in which the abdominal wall was penetrated without visceral injury, the injuries varied from a small wound of a single viscus to penetrating and perforating wounds of several organs. More than a quarter of the patients (26.6 percent) had thoracoabdominal injuries. All types of associated (extra-abdominal) injuries were present in all conceivable sites. The physical status of many of the casualties was only fair or actually poor. Some degree of shock was present in most cases; frequently it was extremely severe. In a representative sample of 957 cases, 14.6 percent of the patients had systolic blood-pressure readings from 0 to 40 mm. Hg, 12.7 percent from 41 to 70 mm. Hg, 26.1 percent from 71 to 100 mm. Hg, and 46.6 percent from 101 to 120 mm. Hg. Often there had been periods, sometimes long periods, of fatigue, exposure, and dietary limitations before the injuries had occurred.

Pulmonary blast injuries deserve special mention. The small number in this series suggests that only the most severe were put on record and that the majority, because they were minimal, were either not recognized or not entered on the charts. The gravity of this particular problem naturally varied with the degree of injury. Casualties who had sustained severe bilateral injuries furnished the anesthetists with many special problems. It was a real achievement to anesthetize a patient with this type of injury without losing him on the table from pulmonary edema. No form of anesthesia, least of all ether, was well tolerated, and it was always difficult to maintain an adequate airway during operation and afterward.

AGENTS AND METHODS

Although a wide variety of anesthetic agents was available in the Mediterranean theater, anesthesia, for practical reasons, was accomplished in more than 90 percent of all cases with ether (table 23). The agents supplied included, in addition to ether, chloroform, ethyl chloride, nitrous oxide, Pentothal, procaine, Pontocaine, cocaine, and oxygen. Methods employed included the open-drop method; the closed-circle flow absorption method, with Heidbrink and McKesson machines; the closed to-and-fro absorption method, with the Beecher model machine; intravenous injection; intratracheal injection; local, regional, and field block; and topical application.

TABLE 23.—*Distribution of anesthetic agents in 3,154 abdominal injuries*

Anesthetic agents	1944		1945		Total	
	Cases	Proportion	Cases	Proportion	Cases	Proportion
		<i>Percent</i>		<i>Percent</i>		<i>Percent</i>
Nitrous oxide-oxygen-ether.....	1, 306	54. 81	642	83. 3	1, 948	61. 77
Ether.....	752	31. 56	48	6. 2	800	25. 37
Ethyl chloride-ether.....	224	9. 40	57	7. 4	281	8. 91
Pentothal-ether.....	49	2. 06	1	. 1	50	1. 59
Chloroform-ether.....	1	. 04	0	0	1	. 03
Nitrous oxide-oxygen-ether- Pentothal.....	1	. 04	0	0	1	. 03
Ether-procaine.....	3	. 13	0	0	3	. 09
Procaine (local).....	5	. 21	1	. 1	6	. 19
Procaine (spinal).....	2	. 08	0	0	2	. 06
Procaine-Pentothal (spinal).....	1	. 04	0	0	1	. 03
Nitrous oxide-oxygen ¹	1	. 04	0	0	1	. 03
Pentothal ²	1	. 04	0	0	1	. 03
Oxygen ³	1	. 04	0	0	1	. 03
Not stated.....	36	1. 51	22	2. 9	58	1. 84
Total.....	2, 383	100. 00	771	100. 0	3, 154	100. 00

¹ Patient died from aspiration of gastric contents following vomiting during induction of anesthesia.

² Simple debridement of thoracoabdominal wound of entrance.

³ Patient unconscious and moribund.

Routine Agents and Method

The 2d Auxiliary Surgical Group found soon after it had become operational that the most satisfactory anesthesia for severely wounded battle casualties was secured by (1) induction by nitrous oxide-oxygen and (2) maintenance by ether-oxygen in a closed carbon dioxide absorption system. This method was adopted and came into general use because of its ready availability, its simplicity of administration, its satisfactory tolerance by patients, and its wide margin of safety. The possible toxic effects of ether on the heart, liver, and kidneys were fully realized, but simplicity of administration and the wide margin of safety were considerations of greater importance in view of the fact that, as already mentioned, the anesthetics were administered by some 45 anesthetists of widely varying training, experience, capabilities, and judgment.

Although ether, combined with oxygen and following induction with nitrous oxide, was the most popular anesthetic agent in this series, its use by the open-drop method was considerably less extensive than might have been expected (table 24). This method was used in 12.5 percent of all cases treated in 1944, when anesthesia machines were in limited supply, but in only 2.7 percent of the operations in 1945, when equipment had become widely available.

Closed anesthesia had many desirable features for military surgery, including conservation of body heat and moisture, the maintenance of a high oxygen content and the control of carbon dioxide content in the blood, ease of attaining and maintaining desired levels of anesthesia, and control of respiration and maintenance of positive pressure when these special conditions had to be met. The necessity for an anesthesia in which these objectives could be accomplished was naturally magnified in casualties in critical condition. There was therefore an increasing use of the closed technique as the war progressed (table 24).

The endotracheal technique also had an extensive and increasing use, which in most cases was essential rather than preferential. By it, a patent airway was provided and maintained, no matter what the position of the patient.

TABLE 24.—*Distribution of techniques of administration of anesthesia in 3,154 abdominal injuries*

Method	1944		1945		Total	
	Cases	Proportion	Cases	Proportion	Cases	Proportion
Inhalation:		<i>Percent</i>		<i>Percent</i>		<i>Percent</i>
Closed.....	2,028	85.1	727	94.3	2,755	87.4
Open.....	298	12.5	21	2.7	319	10.1
Semiopen.....	7	.3	0	0	7	.2
Others.....	14	.6	1	.1	15	.5
Not stated.....	36	1.5	22	2.9	58	1.8
Total.....	2,383	100.0	771	100.0	3,154	100.0

The anesthetist, as a result, had sufficient freedom of action to aspirate blood and accumulated secretions easily via the tube and to supervise or administer transfusions when they were required. The endotracheal technique facilitated the control of respiration by positive pressure and assisted in the attainment of desired levels of anesthesia, while the increased smoothness of respiration achieved with a tube in situ simplified the task of the surgeon working in the abdominal cavity. The endotracheal technique was employed in 1944 in 89.8 percent of the 2,108 cases in which a definite statement was made on the matter. The fact that in 1945 it was employed in every one of the 749 cases in which technique was recorded is an indication of the increased appreciation by the surgeons of the group of its numerous advantages.

Other Agents and Methods

Chloroform.—Why chloroform was used for induction in one case in this series is not clear. The dangers of this agent were so well known to both the surgeons and the anesthetists of the group that there was no temptation to employ it to anesthetize casualties with such injuries as these men had sustained.

Pentothal.—In 1944, Pentothal was used 49 times as an induction agent preceding ether anesthesia and once as an adjunct to spinal analgesia (table 23). In this same year, it was used in one instance as the sole anesthetic agent, for simple debridement of a thoracoabdominal wound of entrance. In 1945, it was used only once, as the induction agent.

The extremely limited use of Pentothal by the surgeons of the 2d Auxiliary Surgical Group has significant implications. This anesthetic agent was reported to have been used extensively elsewhere, in some areas in 95 percent of all cases, and it may be that the discrepancy between this usage and the usage of the group can be explained by the type of cases handled, the problem of supply, the echelon at which surgery was done, or a combination of these factors. In the opinion of the group surgeons, all the well-recognized contraindications to Pentothal were present in most of the abdominal injuries which came under their observation. A large proportion of the patients were in shock. Hemorrhage before hospitalization was often serious, and further loss of blood could be expected during operation. Anoxia of varying degrees resulted from hemorrhage and shock, and the accumulation of secretions in the tracheobronchial tree, hemothorax and pneumothorax, painful respiration, and other derangements of cardiorespiratory physiology furnished other problems. The surgery required was frequently formidable and time consuming. Muscular relaxation was essential during operation, particularly while exploration and closure were being carried out. Endotracheal intubation, which was almost universally employed, was difficult to accomplish under Pentothal anesthesia, because of irritability of the larynx and poor relaxation of the muscles of the jaw. The status of the patient thus militated against the use of Pentothal, while the criteria of desirable anesthesia for this type of injury were difficult or impossible to attain when it was used. Finally, serious reactions often occurred

when the tube was inserted, and a second reaction was likely to occur when the catheter was moved as the patient was shifted on the operating table or when his head was turned.

Nitrous oxide.—Nitrous oxide, although it was used routinely as an induction agent, was never used as the sole anesthetic agent (table 23). It was always employed with oxygen concentrations of at least 20 percent, and many anesthetists preferred concentrations of 30 percent or more. Concentrations of 60 to 75 percent were frequently used, and no difficulties were experienced in the brief periods in which they were necessary. Such concentrations, however, are not compatible with a satisfactory level of anesthesia, and nitrous oxide would therefore have been impractical as the primary anesthetic for patients who, like these, were in shock, who had serious and often multiple wounds, who required prolonged major surgical procedures, and who had to be provided with the highest possible concentrations of oxygen to compensate for the loss of their own oxygen-carrying powers.

Ethyl chloride.—Ethyl chloride was used as an induction agent in a large number of cases (table 23) and was satisfactory for this purpose when it was administered cautiously. It was not ordinarily used in patients who presented poor risks, and it was never used as the sole anesthetic agent.

Spinal analgesia.—Spinal analgesia was not regarded as suitable for front-line military surgery for a number of reasons, including the following: The length, as well as the variability, of the time necessary for surgery; the unstable cardiovascular balance of casualties in shock, who had sustained large blood losses; the frequency of associated wounds in areas which cannot be affected by this anesthetic method; and the undesirability of full consciousness in an apprehensive casualty not long removed from the battlefield. Spinal analgesia was used only 3 times in the 3,154 cases (table 23). In each instance, the patient was in excellent condition and there was no doubt that intra-abdominal injury was minimal.

Procaine.—Procaine was occasionally used to secure regional or field block analgesia (table 23), each time in combination with a light inhalation anesthetic. In retrospect, the combined method seems to have excellent potentialities in military surgery, and it is regrettable that it was not given a more adequate test.

Cocaine.—Cocaine was used according to the ordinary indications for bronchoscopy on conscious patients and, occasionally, to facilitate a difficult intubation.

PREOPERATIVE MANAGEMENT

When a field-hospital platoon was well organized and fully staffed, patients with abdominal and thoracoabdominal injuries were placed in charge of experienced shock teams as soon as they were received from the clearing station. These ideal circumstances did not always exist. In the absence of a shock team, or when the flow of casualties was extremely heavy, both anesthetists and surgeons worked in the resuscitation ward. It was therefore

necessary, as already intimated, for the anesthetist to be familiar with shock therapy because emergencies might arise during which the full responsibility for resuscitation would fall upon him.

It was always desirable for the anesthetist to make a preliminary study of the patient before he received him in the operating room, but during rush periods such contacts were not always possible. The anesthetist, however, always determined the pre-anesthetic medication to be administered in the particular case. As a rule, atropine gr. $\frac{1}{100}$ was given, in combination with morphine if that drug was indicated (p. 76). Before operation, morphine was usually given by the intravenous route.

MANAGEMENT DURING OPERATION

The patient was kept in the shock ward until the anesthetic equipment was in order and the instruments were set up for operation. Resuscitation therapy was interrupted as briefly as possible during his transfer to the operating room. If oxygen, for instance, was being administered, it was discontinued only during the actual interval of transportation by the litter carriers.

Induction was seldom difficult. Many of the wounded had gone without sleep for long periods and were completely exhausted, and those who were in shock, or who had been in shock, were, as usual, easy to anesthetize. Severe excitement stages seldom occurred, in contrast to their relative frequency in civilian practice. This was surprising. It had been expected, if only because of the sounds of Allied and enemy artillery and the unavoidable noise and bustle in a busy surgical tent, that excitement would have been frequent and violent.

Anesthesia was maintained in the lightest possible plane compatible with the surgery required in a given case. Men in the condition of these casualties could not usually tolerate deep planes of anesthesia for more than brief periods of time.

Two of the anesthetists in the group were authorized to employ a preparation of curare, on a trial basis, as a supplementary anesthetic agent, to facilitate intraperitoneal manipulations during periods of light anesthesia.¹ Included in the 26 casualties in whom the method was used were 10 with thoracoabdominal wounds and 13 who had recently been in shock. All received nitrous oxide-oxygen-ether anesthesia by the closed endotracheal technique and were given curare in various dosages and at various times during the operation.

The immediate results of this method were excellent in all cases in which it was tested; there were no postoperative complications and no deaths which could possibly be attributed to the use of curare. Abdominal relaxation was entirely satisfactory in every instance, and ether anesthesia could be maintained in the lower part of the first plane, which was thought to be more desirable than the deeper levels ordinarily necessary in military surgery within the abdomen. Both anesthetists who conducted the trials with curare stressed the importance of employing the endotracheal technique when it was used.

¹ Doud, E. A.; and Shortz, G.: The Use of Curare for Abdominal Surgery in Seriously Injured Patients. *Anesthesiology* 7: 522-525, September 1946.

The foot of the litter was frequently raised before anesthesia was induced, and many operations were performed with the patient in the Trendelenburg position. All anesthetists commented on the fall in blood pressure which occurred when the position was changed. The drop was most notable when patients were changed from the supine to the prone position, or vice versa, but alterations also occurred when they were turned on the side. This phenomenon was interpreted as direct evidence of the instability of the vasomotor system in severely wounded, anesthetized patients. Experience soon showed that unnecessary movement of the patient on the operating table must be avoided, and that when changes of position were necessary, they must be accomplished slowly and gently, so that the decrease in tension would be minimized as far as possible. Ephedrine (gr. $\frac{3}{4}$) was occasionally administered a few minutes before the position was to be changed, in an attempt to produce a general vasoconstriction and increased cardiac output and thus to sustain the blood-pressure level.

A clear airway was maintained at all times. Attention to this point was particularly necessary during the winter, when many of the wounded came to operation with bronchitis and had large accumulations of thick mucoid material. Attention has already been called to the increase in the number of patients handled under endotracheal anesthesia as the anesthetists gained proficiency in this method.

In other respects, the management of patients during operation was also a continuation of resuscitative measures. Pain was abolished by anesthesia. Reestablishment of normal metabolism was aided by the administration of oxygen in high concentrations. Restoration and maintenance of the blood volume were accomplished by transfusions. Solutions of dextrose and saline were used only to combat dehydration. When there had been a decrease in the adequate circulating blood volume, citrated blood in the necessary amounts was administered. Very large amounts (up to 6,500 cc.) were used in patients who had sustained injuries to the major blood vessels. Stimulating drugs were seldom administered.

It is well recognized in civilian practice that the longer the duration of an operation, and therefore of anesthesia, the more likely the patient is to leave the operating table in poor condition and to present postoperative complications. The observation was equally valid in military surgery, but little could be done to alter the unfavorable circumstances. In dealing with seriously wounded men, especially when their wounds were multiple, there were few short cuts available to the surgeon by which the operating time could be reduced. The anesthetist did all in his power to maintain a viable patient, by the use of oxygen, Coramine (nikethamide), ephedrine, Adrenalin (epinephrine hydrochloride), transfusions (sometimes into every extremity), sternal transfusion, and artificial respiration, according to the indications. All that the surgeon could do was to work as quickly as he could in the light of the needs of the patient.

Differences in techniques and in individual speed among the various surgeons of the group, as well as differences in injuries among the casualties, resulted in wide variations in operating time. The average time was between 2½ and 3 hours, but the range was between 45 minutes and 6 hours. The duration of anesthesia was always 10 to 15 minutes longer than the duration of the surgical procedure.

POSTOPERATIVE COMPLICATIONS OF ANESTHETIC ORIGIN

The postoperative care of the patient was the joint responsibility of the anesthetist and the surgeon, with the anesthetist, as a rule, concerned primarily with the prevention of shock and pulmonary complications. In times of stress, however, he was obliged to take over the entire responsibility for postoperative care, including nasogastric suction, the maintenance of an adequate fluid balance, thoracentesis for the removal of fluid and air, to facilitate the pulmonary exchange, and the administration of drugs. The essentials of the postoperative regimen are discussed elsewhere.

Postoperative pulmonary complications which occurred within the first 48 hours after operation were classified as of anesthetic origin. Atelectasis (table 31, p. 206) was most frequent. In most instances, the condition was transitory and cleared uneventfully. No deaths occurred from this cause alone within the specified 48-hour period. The atelectasis found at autopsy and not recognized ante mortem in 12 fatalities which occurred within this period was regarded as an incidental rather than a causative factor; all the patients had serious injuries and other serious postoperative complications.

Prophylaxis against atelectasis included the measures already listed; that is, voluntary coughing, frequent changes of position, measures to relieve pain, and the administration of oxygen. Atropine was also frequently administered, though not if the patient presented any signs of increased pulmonary transudation.

Lobar pneumonia and bronchopneumonia were infrequent complications (p. 206). They might have been expected to occur more often following prolonged anesthesia and operation, especially since, as already noted, the patients had often been fighting in intolerable weather; had suffered long periods of exposure before, and sometimes after, wounding; and often had preexisting upper respiratory infections or tracheobronchitis. Undoubtedly, the prophylactic measures employed routinely after operation and the routine use of penicillin and the sulfonamides prevented serious consequences, even in these cases.

ANESTHETIC-CONNECTED DEATHS

The majority of the 86 deaths which occurred on the operating table (11.4 percent of the total number of fatalities) were caused by shock, hemorrhage, or fulminating infection. Nine, however, were attributable to anesthetic causes. In some of these fatalities, the position had been changed just

before death occurred. In four instances, the patients vomited and aspirated gastric contents. Two similar fatalities, incidentally, occurred on the wards shortly after operation; the patients had not completely reacted, and the fatalities must be charged to inadequate supervision. The same accident occurred in four other cases in which the patients survived.

Two deaths occurred at the conclusion of the operation, during bronchoscopy, presumably from a vagovagal reflex. These cases represented 0.4 percent of the 436 recorded bronchoscopies. The vagovagal reflex is a foreseeable catastrophe, and in each of these cases it had been guarded against by the usual measures, namely, intravenous atropinization just before bronchoscopy was undertaken; light anesthesia; and rapid, careful instrumentation, so that mechanical stimulation of the cough reflex would aid in clearing the air passages. In spite of these precautions, a vagovagal reflex ensued and proved fatal.

CHAPTER XIII

Laparotomy Incisions and Closures, and Wound Dehiscences

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In the 3,154 abdominal injuries treated by teams of the 2d Auxiliary Surgical Group, 2,258 records were sufficiently complete to permit an analysis of the technique of incision and closure, as well as an analysis of the 36 wound dehiscences which occurred in these cases within the period of postoperative observation at forward hospitals (a usual range of 8 to 14 days).

INCISIONS

Of the abdominal incisions in these 2,258 cases, 2,072 (91.8 percent) were vertical, and the remainder were transverse (table 25). The great preponderance of vertical incisions reflects the consensus of the surgeons of the group

TABLE 25.—*Distribution of abdominal incisions and wound dehiscences in 2,258 abdominal injuries*

Incision	Cases	Proportion	Dehiscence	Frequency
Vertical: ¹		<i>Percent</i>	<i>Number</i>	<i>Percent</i>
High midline.....	150	7.2	3	2.0
Low midline.....	268	12.9		
High rectus.....	1,176	56.8	25	2.1
Low rectus.....	140	6.8	3	2.1
High paramedian.....	303	14.6	3	1.0
Low paramedian.....	35	1.7		
Total.....	2,072	100.0	34	
Transverse:				
Subcostal.....	54	29.0	1	1.8
Gridiron.....	46	24.7		
Loin.....	26	14.0		
Anterior ²	60	32.3	1	1.7
Total.....	186	100.0	2	
Grand total.....	2,258		36	1.6

¹ All midrectus, midline, and paramedian incisions are arbitrarily grouped with the appropriate high incisions.

² This was an upper abdominal incision used to connect wounds of entry and exit.

that transverse incisions were of very limited value in war wounds of the abdomen. There were two principal reasons for this opinion:

1. Vertical incisions permitted the extensions which were often necessary to secure satisfactory access to injuries not diagnosed before the abdomen was open.

2. Vertical incisions left the lateral and medial portions of the abdominal wall free for separate incisions for colostomies. Exteriorization of the colon was necessary in a great many of these cases and was best accomplished through another incision rather than through the surgical incision.

CLOSURES

Forty different methods of closure were used in the 2,258 laparotomy wounds on which this chapter is based, the different techniques representing the individual choices of the various surgeons. In general, these methods fell into four large groups (table 26), with closure of the wound in layers by means of catgut sutures supplemented by retention sutures comprising more than two-thirds of the cases. Mass closure, which was utilized in only 252 cases, was usually accomplished by means of heavy braided silk, steel wire, or doubled silkworm gut.

In some of the cases classified as layer closures, the peritoneum was closed with a running suture of catgut, and the other layers were approximated with retention sutures which incorporated skin, fascia, and muscle, or merely skin and fascia. In some cases, interrupted sutures of silk or chromic catgut were used in the anterior fascial layer, while the other layers were approximated with through-and-through sutures. In some cases, the peritoneum was closed by the usual running catgut suture, while nonabsorbable sutures were used in the anterior fascial layer and retention sutures were placed by some one of the usual techniques. When retention sutures were omitted, interrupted cotton or silk sutures were used for all layers, including the peritoneal layer.

TABLE 26.—*Distribution of wound dehiscences in relation to techniques of closure in 2,258 abdominal injuries*

Method	Cases	Proportion	Dehiscence	Frequency
Layer closure:				
Catgut, retention sutures.....	1, 536	Percent 68. 0	Number 22	Percent 1. 4
Interrupted silk or cotton sutures in anterior fascia.....	333	14. 7	7	2. 1
No retention sutures.....	¹ 137	6. 1	1	. 7
Mass closure, through-and-through sutures only....	252	11. 2	6	2. 4
Total.....	2, 258	100. 0	36	1. 6

¹ The majority of patients in this category were submitted to exploration with negative findings or had only minimal lesions. For purposes of comparison, this group should therefore be excluded.

One variation in the technique of closure was the use of a small gauze or rubber drain, placed just beneath the anterior fascia and usually removed about the third day after operation. Gauze or rubber drains were frequently placed in the subcutaneous tissue, to maintain separation of the skin edges for 2 or 3 days. Drainage of the incision was frequently carried out in contaminated wounds. Sometimes the skin was left open; sometimes it was partially closed; and, in selected cases in which hollow viscera had not been perforated, both subcutaneous and subfascial drainage were omitted, and it was sutured primarily.

In spite of the wide variety of techniques of closure which they employed, it was the general feeling of the surgeons in the group that there was no satisfactory substitute for accurate approximation of the various layers of the abdominal wall, combined with some method of retention suturing that would actually maintain wound closure. Mass closure, although it had a real place in the management of patients in precarious condition, invariably meant the sacrifice of accurate layer approximation in the interest of saving time. As a rule, therefore, it was resorted to only when the condition of the patient on the operating table was so serious that prolongation of the procedure seemed likely to deny him his best chance for recovery. Under these circumstances, mass closure was thought to be entirely justified and definitely indicated.

WOUND DEHISCENCES

The 36 wound dehiscences observed in the 2,258 abdominal injuries on which this analysis is based (1.6 percent) all occurred in forward hospitals in 1944 and 1945. If all the casualties could have been traced through the hospitals to which they were evacuated, the incidence might have been considerably higher, as the following figures indicate: Of 250 patients who lived more than 7 days (out of 346 casualties with abdominal and thoracoabdominal injuries operated on by surgeons of the group in 1943), 30 sustained wound dehiscences after they were evacuated to general hospitals.¹

An analysis of these 36 cases reveals the following data:

The accidents happened from 1 to 19 days after operation, the average lapse of time being about 8 days. Exploration of the abdomen had been negative in only one instance; all the other patients had sustained some sort of intra-abdominal injury. The small bowel was injured 21 times, the colon 17, the liver 9, the stomach 7, the kidney 4, the spleen twice, and the urinary bladder twice (the figures are overlapping). The diaphragm was injured in 7 cases, and retroperitoneal hematomas were present in 4 cases. The order of frequency of visceral injuries thus coincided with the order of frequency in the entire series of 3,154 cases (table 7, p. 92), which suggests that wounds to specific viscera cannot be regarded as predisposing to wound disruption.

¹ Report on the Surgery of Abdominal Wounds (unpublished data), submitted to the commanding officer, 2d Auxiliary Surgical Group, 14 April 1944.

The precise cause of the accident was not evident in any of these 36 cases, but the following conditions (multiple in 1 instance) probably contributed to the disruptions: Distention, in 10 cases; wound sepsis, in 7 cases; excessive coughing, in 4 cases; vomiting, spontaneous fistula of the small bowel, delirium, and clostridial myositis which required removal of the entire rectus muscle, in 3 cases each; severe nutritional deficiency in 2 cases; and spontaneous gastric fistula and the use of the laparotomy incision for the colostomy, in 1 case each.

All the principal methods of closure failed at least once in these 36 cases (table 26), and most of them failed in several. Layer closure with nonabsorbable sutures of silk or cotton in the anterior fascia showed no superiority over closure with catgut sutures. In fact, on the basis of the available figures (table 26), the frequency was somewhat greater when nonabsorbable sutures were used. The incidence of disruption, as might have been expected, was higher for mass closure than for either of the two principal methods of layer closure.

Retention sutures were used in the primary closure in 35 of the 36 cases. In the single case in which they were omitted, a running suture of plain catgut was used in the peritoneal layer, the anterior fascia was closed with interrupted sutures of chromic catgut, and a Penrose drain was placed in the subfascial space.

The figures concerning dehiscence in relation to the method of employing retention sutures are of interest though of no statistical value (table 27). When they were placed through the skin and the fascia (either as a loop or a figure-of-eight), there were 2 wound disruptions in each 100 cases. When they included the skin, the fascia, and the muscle, there were 2.1 disruptions in each 100 cases. When mass closure was employed, there were 2.4 disruptions in each 100 cases. When, however, layer closure (closure of one or more layers, with the skin usually left widely open) was combined with through-and-through retention suturing, with all layers of the abdominal wall, including the peritoneum, incorporated in the retention sutures, there was only 1 disruption in each 480 cases (0.2 percent).

TABLE 27.—*Distribution of wound dehiscences in relation to techniques of retention suturing in 2,121 abdominal injuries*

Method	Cases	Proportion	Dehiscence ¹	Frequency
		<i>Percent</i>	<i>Number</i>	<i>Percent</i>
Through skin and fascia.....	813	38.3	16	2.0
Through skin, fascia, and muscle.....	576	27.2	12	2.1
Through all layers of abdominal wall:				
With layer closure.....	480	22.6	1	.2
With mass closure.....	252	11.9	6	2.4
Total.....	2,121	100.0	35	1.6

¹ In 1 case of wound separation not included in this table, retention sutures were not used.

Catgut was used for the layer closure in the majority of cases in which this combined technique was employed. The through-and-through retention sutures were inserted in one of two ways: They were either pulled up and tied fairly snugly in the midline, or they were tied laterally over rubber tubes placed on each side of the incision. In only one instance in this series did a possible mechanical intestinal obstruction result from the employment of this technique. The obstructive signs in this case disappeared when the through-and-through sutures were released on the fifth postoperative day, and recovery thereafter was smooth.

The use of pulley sutures, either for mass closure or as a method of retention suturing to supplement layer closure, produced almost uniformly poor results in this series. Reports from general hospitals mentioned a number of cases in which strangulation of the tissues was followed by massive sloughs and which usually required secondary wound closure.

Management

In 7 of these 36 instances of wound dehiscence, the wound was taped and no surgery was done. In 28 cases, secondary suture was carried out. Silk through-and-through sutures were used in 16 cases, wire through-and-through sutures in 11 cases, and silk figure-of-eight sutures in 1 case. The remaining patient died on the operating table before surgery could be started. Two patients, one of whom had been treated conservatively and the other by secondary suture, later presented small intestinal fistulas.

Causes of Death

There were 7 deaths in these 36 cases, 5 of which were apparently caused by the wound dehiscence itself. One patient, as already noted, died on the operating table, partly from shock and partly from the anesthetic. In one case, fatal peritonitis followed retraction of a colostomy (which had been exteriorized in the laparotomy wound) into the peritoneal cavity. In one case, peritonitis resulted from two leaking areas in the small bowel caused by trauma from the through-and-through wire sutures used in the secondary closure. In one case, death occurred 4 hours after secondary suture; aspiration of vomitus during anesthesia was followed by fatal pulmonary and bronchial edema. In the remaining case, which was treated conservatively, death was the result of acute mechanical intestinal obstruction.

Prophylaxis

The large number of wound dehiscences reported in 1943, to which reference has already been made,² provoked serious consideration among the surgeons of the 2d Auxiliary Surgical Group. The whole subject of wound closure was studied, and special attention was given to measures which might prevent future accidents. Analysis of the cases reported in 1943 revealed certain

² See footnote 1, p. 193.

practices which could be considered as possibly causative. Thus it was not uncommon in the early experience in the North African theater to omit retention sutures in laparotomy wounds, even though the incisions were usually closed in layers. It was also not uncommon to exteriorize a damaged segment of colon in the laparotomy incision rather than in a separate small incision. Finally, it was a rather common practice to evacuate patients with abdominal wounds prematurely (that is, before the optimal interval of 10 to 14 days), even though evacuation necessitated long ambulance hauls over terrain that was often rough. The policy of eliminating all of these practices unquestionably played a part in reducing the incidence of wound dehiscence in 1944 and 1945.

No policy, however, and no technique could entirely prevent wound dehiscence, to which there existed a natural tendency in penetrating and perforating injuries of the abdomen. For this there were a number of reasons:

1. Massive soiling of the peritoneal cavity, as the result of perforation of hollow viscera, produced peritonitis, either chemical or bacterial, in a large proportion of cases and also resulted in heavy contamination of the laparotomy incision. Clinical sepsis, with its deleterious effects on sound wound healing, not infrequently followed.

2. Prolonged nasogastric suction was essential in these injuries at a time when nutritional reserves were likely to be critically low.

3. The rather high incidence of pulmonary complications, especially during the winter months, and the resulting severe and protracted cough often added considerably to the strain on the abdominal incision.

4. The tactical situation was sometimes such that patients with abdominal injuries had to be evacuated soon after operation, in spite of the undesirability of the practice. The combined effect of these various uncontrollable factors explains why even in 1944 and 1945, when conscientious efforts were made to prevent it, the incidence of wound dehiscence was far higher among military casualties with abdominal injuries than it would be in a series of nontraumatic abdominal operations in civilian life.

The measures employed to prevent wound disruption were multiple and, if they were to be effective, had to be instituted as soon as the incision was made. The trauma of both incision and closure was kept to a minimum. Gross soiling and contamination of the incision were avoided in every possible way. The Halstedian principles of tissue handling were sedulously employed to prevent wound reaction, the absence of which favored uncomplicated wound healing. Certain physiologic and chemical principles were also borne in mind: The erythrocyte count was kept at 4 million per cubic millimeter, or higher, and the hemoglobin level was kept above 12 gm. percent. Plasma was given in amounts of 250 cc. once or twice daily as long as Wangensteen decompression was required. Vitamin C was given parenterally over the same period and was given orally as soon as feeding by mouth could be resumed. The patient was evacuated with the retention sutures still in situ, and, during transit, additional abdominal support was provided by a binder, preferably of the scultetus type.

CHAPTER XIV

Penicillin and Sulfonamide Therapy (2,410 Casualties)

James C. Drye, M. D.

Prior to May 1944, patients with abdominal injuries were treated with some one of the sulfonamide drugs, usually parenterally. At that time, penicillin was introduced, and thereafter it became part of the routine of treatment.

The basis for this analysis is formed by 2,410 patients who received a sulfonamide drug, penicillin, or both agents. The series is selective in that it excludes men who presented no intraperitoneal injury at operation, patients who died on the operating table, and patients whose records were deficient in data concerning antibacterial therapy. Since the analysis was not undertaken until the end of hostilities, no control series exists. For that matter, there would have been small justification for withholding these presumably beneficial agents from any wounded man in order to provide such controls.

METHODS OF ADMINISTRATION

Until penicillin became available, sulfadiazine sodium was given by the intravenous route, usually in amounts of 2.5 gm. at 12-hour intervals. The first dose was customarily given in the shock ward, as part of the routine of resuscitation. After penicillin had become available in sufficient quantities to be supplied in the division clearing stations, the first intramuscular injection was given at that echelon. Doses in the field hospitals ranged from 5,000 to 25,000 units at 3-hour intervals.

Although crystalline sulfanilamide was available for intraperitoneal use throughout the war, it was not used regularly by this route in the Mediterranean Theater of Operations, and the same was true of penicillin after it became available. Some surgeons used either agent, or both, with fair regularity, and most surgeons used one or the other in selected cases; the decision was always individual. There was a notable tendency to use the intraperitoneal route whenever wounds were severe or contamination was extensive. Crystalline sulfanilamide was used in doses of 5 to 10 gm. and penicillin in doses of 50,000 units.

The postoperative use of both agents also varied with the practices of individual surgeons. Some used one or the other routinely; some only when complications developed. Some preferred to employ both at the same time. Sometimes one was discontinued in favor of the other. Dosages varied widely.

CASE FATALITY RATES

Because of the variations in the use of the sulfonamides and penicillin, as well as the variations in methods of administration and dosages, a precise statistical analysis of the cases in which they were employed was not possible. The most practical means of determining their relative efficacy was to analyze the case fatality rates in peritonitis.

The case fatality rate from all causes in the 2,410 cases in which one or the other, or both, of these agents was used was 23.2 percent (560 deaths). There were 422 deaths (24.4 percent) in the 1,732 cases treated in 1944 and 138 (20.4 percent) in the 678 cases treated in 1945. These rates closely parallel the case fatality rates for the whole series.

One hundred and thirty-seven of the 560 deaths were caused by peritonitis (table 28). These deaths cannot be properly discussed until they are broken down into two categories. As is pointed out elsewhere (p. 127), two types of fatalities from peritonitis were observed in abdominal injuries in World War II. In the first, so-called contamination type, there was massive peritoneal soiling, the casualties were in shock and did not respond to the usual measures of resuscitation, and death occurred within the first 48 hours after operation. In the second type of fatality, the patients presented the classical type of suppurative peritonitis. The clinical manifestations were those usually observed, including fever, vomiting, abdominal tenderness, distention, and ileus. Death from this variety of peritonitis commonly occurred between the 4th and 11th postoperative days. In this analysis, no deaths were attributed to the classical form of peritonitis if they occurred within the first 3 days after operation.

TABLE 28.—Comparative case fatality rates from massive peritoneal contamination (shock) and bacterial peritonitis in 2,410 abdominal injuries

Year	Cases	Massive peritoneal contamination		Bacterial peritonitis	
		Deaths	Case fatality rate	Deaths	Case fatality rate
1944.....	1, 732	58	3. 4	32	1. 8
1945.....	678	37	5. 5	10	1. 5
Total.....	2, 410	95	3. 9	42	1. 7

In some cases in which peritonitis developed, the peritoneal infection was, at the most, a contributory cause of death, and antibacterial agents could not have been expected to influence the final outcome. This group included the patients who were moribund on admission to the hospital, those who died from such accidents as aspiration of vomitus, those with serious intercurrent

disease, and those with serious or fatal noninfectious extra-abdominal injuries. No death in this group of cases was attributed to peritonitis in this analysis.

On the basis of these criteria of selection, the case fatality rate for the classical type of peritonitis was found to be 1.7 percent, against 3.9 percent for the contamination type (table 28).

In an unplanned investigation such as this, in which there is no control series and complete statistical data are lacking, it would not be permissible to draw anything beyond tentative conclusions concerning the possible benefits of chemotherapeutic and antibiotic agents in abdominal injuries (tables 29 and 30). It would also not be permissible to attempt precise comparisons between the effects of the sulfonamides and penicillin, chiefly because the advent of penicillin coincided closely with two other events which greatly improved the management, and therefore improved the prognosis, of battle-incurred abdominal injuries in the Mediterranean Theater of Operations. The first of these events was the establishment of a theater blood bank in Naples. The second

TABLE 29.—*Influence of antibacterial therapy on comparative case fatality rates in 1,526 abdominal injuries*

Therapy	Cases	Deaths			Case fatality rate		
		Total	From peritoneal contamination	From bacterial peritonitis	Total	From peritoneal contamination	From bacterial peritonitis
1944:							
Parenteral sulfadiazine alone or with intraperitoneal sulfanilamide.....	361	117	12	18	32.4	3.3	5.0
Parenteral penicillin alone or with intraperitoneal penicillin.....	727	158	18	2	21.7	2.5	.3
1945:							
Parenteral sulfadiazine alone or with intraperitoneal sulfanilamide.....	0	0	0	0	0	0	0
Parenteral penicillin alone or with intraperitoneal penicillin.....	438	97	10	4	22.1	2.3	.9
Totals, 1944-45:							
Parenteral sulfadiazine alone or with intraperitoneal sulfanilamide.....	361	117	12	18	32.4	3.3	5.0
Parenteral penicillin alone or with intraperitoneal penicillin.....	1,165	255	28	6	21.9	2.4	.5

TABLE 30.—*Influence of route of administration of antibacterial therapy on comparative case fatality rates in 2,410 abdominal injuries*

Routes of administration	Cases	Deaths			Case fatality rate		
		Total	From peritoneal contamination	From bacterial peritonitis	Total	From peritoneal contamination	From bacterial peritonitis
1944:							
Parenteral route only ¹ -----	635	131	4	5	20.6	0.6	0.8
Parenteral and intraperitoneal routes ² -----	1,097	291	49	27	26.5	4.5	2.5
1945:							
Parenteral route only ¹ -----	341	55	8	2	16.1	2.3	.6
Parenteral and intraperitoneal routes ² -----	337	83	29	8	24.6	8.6	2.4
Totals, 1944-45:							
Parenteral route only ¹ -----	976	186	12	7	19.1	1.2	.7
Parenteral and intraperitoneal routes ² -----	1,434	374	78	35	26.1	5.4	2.4

¹ Penicillin or sulfadiazine.² Intraperitoneal sulfanilamide with parenteral sulfadiazine or penicillin, or intraperitoneal and parenteral penicillin.

was the wide distribution, among the surgical teams, of portable machines for anesthesia, which thereafter was much more efficient. The decrease in the case fatality rates for abdominal injuries after the spring of 1944 therefore cannot be attributed solely to the advent of penicillin but must be regarded, at least in part, as a reflection of these other benefits. Finally, there must be taken into account the increasing experience of the surgical teams.

In addition to these major considerations, climatic and tactical factors must be taken into account in the comparison of the relative effects of the sulfonamides and penicillin in abdominal injuries. The sulfonamide-treated cases were all observed in 1944, most of them in the first 4 months of the year. This particular period covered the fighting before Cassino and on the Anzio beachhead. Conditions of weather and terrain and facilities for evacuation were notoriously unfavorable during both campaigns. As a rule, severe exposure was commonplace, and the evacuation timelag was frequently prolonged. The case fatality rate, which was markedly elevated at this time, was undoubtedly influenced by both factors. The corollary of this reasoning is that the improvement which occurred later in 1944 and continued into 1945 cannot fairly be attributed only to the greater efficiency of penicillin, and the figures (table 29) must be interpreted in the light of these facts.

When penicillin was substituted for the sulfonamide drugs (table 29), there was a very slight reduction in the case fatality rate in peritoneal con-

tamination but a very considerable reduction in the rate in bacterial peritonitis. The change in therapy, as already noted, occurred in May 1944. The case fatality rate for all abdominal injuries fell from 32.8 percent in the first quarter of 1944 to 22.4 percent for the April–December period (p. 216). This decrease was disproportionately less than the decline in the case fatality rate observed in peritonitis alone. It was the opinion of the surgeons of the 2d Auxiliary Surgical Group that the decline in deaths from peritonitis was too marked and too abrupt to be explained only by improvement in weather and combat conditions, even in combination with increasing experience in the management of abdominal injuries. They therefore concluded, at least tentatively, that penicillin was more efficacious than the sulfonamides in the prevention and treatment of peritonitis secondary to war wounds of the abdomen.

The case fatality rates calculated according to route of use might seem to suggest, on casual inspection, that deaths were more numerous when the combined parenteral-intraperitoneal method was employed than when the parenteral route alone was used (table 30). The conclusion would be completely unjustified. Analysis of the individual cases which make up the series shows that antibacterial agents were usually used by the intraperitoneal route only when wounds were extensive and contamination was serious. The higher case fatality rate therefore merely reflects the fact that these agents were used intraperitoneally only in the most severely wounded patients. Whether the rate would have been even higher if this route had not been employed it is, of course, not possible to say.

CHAPTER XV

Postoperative Complications: Prophylaxis and Therapy

James C. Drye, M. D., and W. Philip Giddings, M. D.

The records of the 2d Auxiliary Surgical Group are not complete in respect to postoperative complications and are particularly fragmentary in respect to less severe and nonfatal types. For these deficiencies, there are two explanations. The first is, as already pointed out, that the circumstances of war did not permit the keeping of clinical records which were complete and accurate in all details. The second is that many postoperative processes which in civilian practice would be regarded as complications were so frequent in battle wounds that they came to be regarded as almost implicit in certain injuries and after certain operations. Such complications were seldom made a matter of record. That is why, in this series, it is impossible to make any accurate determination of mild incisional sepsis, ileus of brief duration, pulmonary complications of minor severity, and similar processes.

Early in the war, it was found that premature evacuation of casualties with abdominal injuries increased the incidence of wound dehiscence, ileus, peritonitis, and other major postoperative complications. The trauma and discomfort of ambulance transport over rough roads, as well as the loss of continuity of treatment in a critical stage of convalescence, made these results almost inevitable. It therefore became the policy that, whenever the tactical situation permitted, patients with abdominal wounds should not be evacuated earlier than the eighth day after operation (p. 85). In practice, evacuation was delayed for 14 days in a great many cases, and, if the injuries were unusually severe, it was sometimes delayed for as long as 30 days. The tactical situation frequently prevented complete adherence to this policy, but the majority of the patients in this series were nevertheless held in forward hospitals from 8 to 14 days. It was the emphatic opinion of the surgeons of the group that this policy, quite as much as any other consideration, produced the low morbidity and case fatality rates generally observed in casualties with abdominal injuries in World War II.

Only 3,090 of the 3,154 records used in this analysis were sufficiently complete to permit an analysis of the presence or absence of postoperative complications. All of the complications discussed are also discussed under special headings in other sections of this report. In spite of the inevitable repetition, however, it was thought worthwhile to bring them together at this point and comment upon them briefly.

PULMONARY COMPLICATIONS

In spite of the known frequency of postoperative pulmonary complications, their recorded occurrence is less accurate than that of other complications in this series (table 31). In addition to the general reasons already listed, still other reasons can be advanced to explain this situation: An accurate diagnosis of pulmonary conditions was likely to be difficult under field conditions. Even though an adequate physical examination was sometimes impossible, the diagnosis usually had to be based entirely on physical findings. Postoperative roentgenograms of the chest were seldom made. When they were, they were usually unsatisfactory because of the limited technical facilities in forward hospitals. In many other instances, examination was precluded by the precarious state of the patient or by the presence of heavy plaster casts.

Sputum examinations were seldom made, because bacteriologic facilities were not easily available. For these various reasons, the statistics tabulated are admittedly deficient. They are, however, in accord with mature, clinical impressions, and the trends which they indicate can be accepted as accurate.

Pulmonary complications were frequent after operation in patients with abdominal injuries, as might have been expected, because conditions in the theater favored the development of such complications. A large proportion of the casualties occurred during the period of the year which is cold and wet in Italy (p. 216). Troops fought in mud and were almost constantly exposed to heavy rainfall or snow from October through March. As a result, more casualties were received with established respiratory infections during this period than during the summer months, the common cold following the same seasonal trend in Italy as it does in the temperate zones of the United States. Furthermore, many patients passed the critical hours immediately before and after operation in damp tents (fig. 26), in environmental temperatures of 60° or 50° F., or lower. All of these circumstances combined to cause a high incidence of infectious pulmonary complications, particularly during the winter months.

The recorded case fatality rate, almost 40 percent (table 31), is further proof that only the most severe pulmonary complications were listed. It was the general impression that their severity, as well as their frequency, was greater during the winter than during the summer, and the case fatality rates for the two periods lent support to this opinion. Available figures, however (table 31), suggest that the presence of associated chest wounds did not appreciably affect either the frequency or the case fatality rate of the usual infectious pulmonary complications which occurred in abdominal casualties.

There seems no doubt that most of the infectious complications were atelectatic in character and that they arose on the basis of bronchitis or some other respiratory infection already present at the time of operation. In other words, they were those which might be expected to develop in a patient



FIGURE 26.—Conditions of surgery in field hospital in Italy in winter of 1944-45.
Resuscitation tent.

population of combat troops carrying a heavy prewounding load of endemic respiratory infections.

The only two instances of lung abscess, both of which were fatal, were not associated with thoracic injuries. Empyema, on the other hand, was associated with chest injuries in 25 of the 29 recorded cases, 11 of which were fatal. All 4 fatalities which occurred in the 7 instances of bile empyema were associated with thoracoabdominal wounds.

The fact that hydropneumothorax was recorded only 91 times in the 3,090 abdominal injuries suggests that note was taken of only the more serious cases, in which repeated thoracenteses were necessary. The incidence was undoubtedly much higher. In most instances, 2 to 3 aspirations of the pleural cavity were sufficient.

The actual incidence of both pulmonary edema and the so-called traumatic wet lung is known to be considerably greater than the recorded figures indicate (table 31). Pulmonary edema was readily precipitated in severely wounded patients, especially in those in shock, if intravenous fluids were given in too great quantities or too rapidly.

As was pointed out in the discussion of the multiplicity factor, the incidence of postoperative pulmonary complications tended to rise with the increase in the number of viscera injured, the observation being, however, of clinical rather than statistical significance (table 32). The explanation was simple: the more

TABLE 31.—*Distribution of recorded pulmonary complications in 3,090 abdominal injuries*

Complication	With thoracoabdominal or associated chest wounds (965) ¹		Without thoracoabdominal or associated chest wounds (2,125) ¹		Total	
	Cases	Deaths	Cases	Deaths	Cases	Deaths
Hydropneumothorax.....	86	9	5	0	91	9
Atelectasis.....	23	11	37	5	60	16
Bronchopneumonia.....	12	6	39	19	51	25
Empyema.....	25	9	4	2	29	11
Pulmonary embolism.....	5	5	17	16	22	21
Pulmonary edema.....	6	4	16	11	22	15
Bronchopleural fistula.....	18	5	0	0	18	5
"Consolidation".....	6	4	8	4	14	8
Wet lung.....	4	3	9	4	13	7
Aspiration of vomitus.....	1	1	7	5	8	6
Lobar pneumonia.....	2	2	5	5	7	7
Bile empyema.....	6	4	1	0	7	4
Blast.....	2	1	4	3	6	4
Bronchitis.....	2	1	1	1	3	2
Lung abscess.....	0	0	2	2	2	2
Other.....	1	1	6	0	7	1
Total.....	199	66	161	77	360	143

¹ Associated wounds include nonpenetrating trauma to the chest wall.TABLE 32.—*Influence of multiplicity factor on development of infectious thoracopulmonary complications in 2,831 abdominal injuries*

Item	Number of organs involved					Total cases
	One	Two	Three	Four	Five	
Cases.....	1, 348	1, 014	350	96	23	2, 831
Complication.....	87	55	40	11	3	196
Incidence (percent).....	6. 5	5. 4	11. 4	11. 5	13. 0	7. 0

severely wounded patients were the ones most likely to present stagnation of the tracheobronchial secretions, and atelectasis and pneumonia were therefore more likely to develop in them.

Prophylaxis and therapy.—The prophylaxis and therapy of pulmonary complications were both based on a few fundamental principles. The most efficient prophylaxis consisted of expertly administered anesthesia, with par-

ticular attention to a careful tracheobronchial toilet at the close of the operation. Catheter aspiration or aspiration bronchoscopy was part of the established routine in patients with thoracoabdominal injuries and associated chest wounds and was frequently carried out in patients with other types of injuries, just before they were taken off the operating table. Dressings were applied so as not to restrict the respiratory excursion.

After operation, the first essential was to maintain a clear tracheobronchial tree. For this, frequent changes of position and frequent coughing were essential. In patients with multiple wounds, particularly those in large, bulky casts, changes of position were not always easy to accomplish. Firm manual pressure was of great aid to patients endeavoring to cough, and many learned to support their own incisions.

If the patients refused to cough or could not cough satisfactorily, tracheobronchial suction was again resorted to. If it was not effective, bronchoscopy was employed without delay. Oxygen therapy was employed according to the indications. All of these measures, which were standard practice, approximate the usual methods of prevention of postoperative complications in civilian practices.

Patients with wet lungs, who required repeated tracheal aspirations to clear the airways effectively, were usually treated with tracheal catheter in situ. It was aspirated at regular intervals, and oxygen was usually administered in the interim, sometimes under slight pressure.

Morphine was administered in as small doses and as infrequently as possible, to prevent depression of the respiration. The amount necessary could frequently be reduced by the use of nerve blocks for the relief of pain. Some surgeons of the group made it a practice to block the intercostal nerves from within, while they were exposed in thoracoabdominal wounds, or to perform nerve block before the patient was removed from the operating table.

Pulmonary edema could usually be prevented by care in the administration of intravenous fluids. Hypodermoclysis was occasionally resorted to instead of infusion, but the method was not looked upon with favor because of the possibility of introducing anaerobic organisms. In a few instances in which pulmonary edema appeared soon after operation, venesection was done, with apparent benefit. Preparations of digitalis by the parenteral route also seemed of benefit. These measures were resorted to on empirical grounds. Atropine was used according to the indications.

Although penicillin and sulfadiazine were given routinely as part of the prevention and treatment of pulmonary complications, pneumonias still developed in patients who were adequately treated by these agents. It was thought, although this was merely a clinical impression, that patients with pneumonic processes who did not respond to chemotherapy and antibiotic therapy, or who died under proper treatment, might have the so-called atypical variety of pneumonia.

NONPULMONARY COMPLICATIONS

Shock.—Shock was the most important of all postoperative complications (p. 119). Its correct incidence is undoubtedly greater than the figures suggest. The role it played in the case fatality rate in these 3,090 cases is shown by the fact that 64 percent (472) of all the deaths (737) were attributable to it. It was the most frequent cause of death in the first 48 hours after operation, and it was almost invariably fatal in the small number of patients in whom it persisted after this time.

The essentials of management were blood replacement, oxygen by nasal catheter or the Boothby mask, and careful analgesic medication administered with due care to prevent further depression. These measures were instituted as soon as the patient was seen and were continued after operation as long as necessary. When morphine was indicated, the dose was kept small, and it was preferably administered by the intravenous route.

Peritonitis.—Peritonitis of some degree existed a priori in all patients with perforations of hollow viscera. Its frequency can be estimated from the fact that injuries of this type were present in more than half of all cases in the series. The true ante mortem incidence of invasive bacterial peritonitis is not known. It existed in all degrees of virulence, sometimes in so mild a form that the diagnosis was merely academic and sometimes, at the other extreme, in such overwhelming contamination and infection that the patient died within a few hours. The great majority of patients who presented the usual clinical picture of ileus, abdominal tenderness, and fever recovered uneventfully, but 91 (12.3 percent) of all the deaths were due to this cause. The most effective measures in both prevention and therapy were decompression of the gastrointestinal tract and routine parenteral administration of sulfadiazine and penicillin.

Abdominal distention.—Abdominal distention, whether as a manifestation of peritonitis or from other causes, was uncommon in this series, undoubtedly as the direct result of the routine practice of postoperative decompression of the gastrointestinal tract. Two- or three-bottle siphonage suction was used, by the Wangenstein method; discarded 1-liter flasks originally used for intravenous solutions were excellent for this purpose. The tube was usually left in place from 3 to 6 days. It was essential to leave it in situ until there was definite evidence of return of intestinal tonus and motility; most instances of distention followed its premature removal.

This simple method of preventing and controlling abdominal distention and subsequent ileus was chiefly responsible for the low incidence of a complication which, with its sequelae, had plagued military surgeons in earlier wars.

Intestinal obstruction.—Mechanical intestinal obstruction was recorded in 21 cases, in all but 1 instance in patients with wounds of the small intestine (p. 250). The figure is probably correct; the condition is too serious a complication to be overlooked. Operation was performed in only 3 patients, all of whom survived; there were 7 deaths in the remaining 18 cases. Although

operation seems to have been withheld in some of the fatal cases because the patients were in precarious condition, a review of the records suggests that some of these lives might have been saved by a more aggressive policy of surgical intervention.

Incisional sepsis.—Minor degrees of incisional sepsis, which were seldom recorded, were not uncommon. Major sepsis was infrequent, the 32 recorded cases representing approximately 1 percent of the whole series.

The best method of preventing wound infection was found to be the routine drainage of subcutaneous tissues. It became the established practice to accomplish this by the following technique: A thin strip of fine-mesh gauze or a small bandage was laid longitudinally in the incision, before the skin was closed, so as to keep the cutaneous margins and subcutaneous fat separated. The skin sutures were then tied loosely across it. The gauze was left in place until the second or third day. It was the clinical impression that drainage of subcutaneous fat, which was particularly vulnerable to infection, materially expedited healing by first intention.

Because the incisions used for abdominal wounds were almost always potentially infected, it was necessary to change the dressings and inspect the wounds more frequently than is customary in civilian practice. Surgical drainage was instituted promptly whenever suppuration developed.

Wound dehiscence.—The incidence of wound dehiscence was higher in this series than in civilian practice, for reasons outlined elsewhere (p. 196). Prompt resuture was the treatment of choice.

Gastrointestinal fistula.—The 23 instances of gastrointestinal fistula recorded in this series represent a relatively small incidence in view of the large number of perforations of hollow viscera. It is likely that additional fistulas were observed after the patients were evacuated, since this is frequently a somewhat delayed development.

Gastrointestinal fistulas, while they did not represent immediate emergencies, were considered an indication for priority of evacuation to fixed hospitals, where more adequate therapeutic facilities were available than in field and evacuation hospitals. The basis of treatment was to provide the patient with maximum nutritional support and to employ gastrointestinal decompression whenever this measure was indicated.

Intraperitoneal abscess.—The 15 subhepatic or subphrenic abscesses and the 9 pelvic abscesses recorded in this series represent an incidence of slightly less than 1 percent. This is not excessive, in view of the type of wounds treated and the fact that this is another complication which probably presented itself in a number of other cases after evacuation. The treatment was surgical drainage.

Anaerobic infections.—Clostridial infections of the abdomen were encountered after operation only eight times. Death occurred in every instance. In five cases, the retroperitoneal space was infected. In the other three cases, the process involved the abdominal wall, and en bloc excision of the entire rectus abdominis muscle on one side was followed by wound dehiscence.

Treatment always included massive doses of polyvalent anti-gas-gangrene sera, in addition to penicillin and sulfadiazine in large doses.

Secondary hemorrhage.—Only eight instances of secondary hemorrhage were recorded. There is no doubt that moderate bleeding, such as might occur after removal of a pack from the liver, took place in many other cases but was not recorded. In 2 of the 8 cases, the bleeding was from remote vessels, in 1 instance an intercostal artery and in 1 instance the femoral artery. In the other 6 cases, the hemorrhage was from sutured gastric wounds (p. 230).

These six cases comprise the only recorded instances of gastrointestinal bleeding, which is probably to be explained by the fact that, although a very large number of gastrointestinal repairs were carried out, the operations were chiefly on the small intestine, in which suture lines are less likely to bleed than suture lines in the colon. The policy of exteriorization of wounds of the colon thus not only protected the patient against necrosis and leakage but apparently reduced the risk of postoperative hemorrhage as well.

Thromboembolism.—The 22 instances of proved or suspected pulmonary embolism, 21 of which were fatal, must be considered as merely an approximation, since autopsies were not performed in at least 40 percent of all deaths. Nonfatal emboli undoubtedly occurred, but they were either not diagnosed or not recorded. Nonfatal thrombophlebitis and phlebothrombosis were recorded only five times but were probably much more frequent.

In the majority of cases in which emboli were shown to have originated in the veins of the leg, there had also been wounds in the involved extremities. In one instance, the autopsy showed the source of the embolus to be the right external and common iliac veins. This particular patient had sustained a wound of the pelvis, with perforation of the bladder and extensive extraperitoneal trauma, and the surgeon, because of the evidence of severe damage near the great vessels in the right side of the pelvis, debated at operation the propriety of prophylactic interruption of the right common iliac vein, even though it had not been directly traumatized. Unfortunately, he did not act affirmatively on his premonition of trouble, and the man lost his life.

Prophylactic or therapeutic interruption of the femoral veins was employed only occasionally in this series of abdominal injuries. This prophylactic procedure should probably have been employed more frequently, in view of the apparent tendency for an embolism to arise in a wounded extremity, especially when an associated abdominal wound increased the hazard. This was particularly true when, as was usually the case, the limb had to be immobilized in plaster of paris, which not only compounded the risk of thromboembolism but also precluded frequent examinations for the detection of postoperative phlebothrombosis. The case history just related also indicates the importance of giving serious consideration to ligation of the great veins of the pelvis when trauma to adjacent tissues has occurred.

Since the anticoagulant drugs (heparin, Dicumarol (bishydroxycoumarin, U. S. P.)) were not available in field hospitals, no comment can be made on their efficacy in the treatment of thromboembolism. It can be said, however,

that in many abdominal injuries their employment would be both difficult and dangerous. They would certainly be contraindicated in wounds of the liver or in associated wounds of the soft tissues, lung, or head, because of the risk of hemorrhage. Even in future wars, it is doubtful that heparin could be made available in adequate quantities and equally doubtful that adequate facilities could be provided for the use of Dicumarol under field conditions. For these reasons, if needless fatalities from pulmonary embolism are to be prevented, it would seem that the military surgeon of the future must be well versed in the indications for, and techniques of, prophylactic interruption of the femoral veins.

Anuria.—Anuria (posttraumatic renal failure, lower nephron nephrosis, pigment nephropathy) was recorded in 36 cases in this series, 35 of which were fatal. Very little was known about this complication early in the war, and there is no doubt that the diagnosis was overlooked at that time. With increasing experience, however, surgeons became aware of its frequency and its dangers and were even able to predict that it might develop in certain cases.

There were four major warning signs of impending renal failure:

1. While it was insidious in onset and usually could not be diagnosed positively until the third or fourth postoperative day, it was particularly likely to occur in the most severely wounded men, particularly when shock had been profound and of long duration. Earlier than the third day, renal failure could not be distinguished from the physiologic oliguria which accompanied shock and which might persist for 48 hours after operation.

2. Renal failure was a possibility whenever diuresis did not occur at the end of this time and the patient, if he was out of shock, continued to be oliguric. It was thus of prime importance to measure the daily volume of urine accurately. Once shock had been controlled and the blood pressure was tending to a normal level, a 24-hour output of urine of less than 700 cc. was an ominous sign.

3. Hypertension was the next warning sign. With developing renal failure, there was usually a slow increase in the blood pressure, which sometimes climbed to 180/120 mm. Hg.

4. Azotemia was another sign of impending trouble. It was not uncommon immediately after operation, when the nonprotein nitrogen level of the blood might reach 80 mg. percent. Usually, however, the value returned to normal on or about the second postoperative day, when diuresis occurred. Persistent or increasing azotemia after this time usually meant impending anuria. The nonprotein nitrogen of the blood was readily determined under field conditions by the copper sulfate method.

The treatment of renal failure was chiefly under the direction of the Board for the Study of the Severely Wounded, as a research project, and extensive details are contained in the report of that group.¹ Results were disheartening. While management was not standardized, the general plan was to restrict

¹ Medical Department, United States Army, Surgery in World War II. The Physiologic Effects of Wounds. Washington: U. S. Government Printing Office, 1952.

fluid allowances to 1,000 cc. or less for the 24-hour period, this being the minimum required to compensate for insensible fluid losses. Salt was withheld entirely. The purpose of these restrictions was to prevent the pulmonary edema which was common in these cases. The urinary output was accurately measured by means of an indwelling catheter. Diuretics, including ethanol (5 percent) by vein, were tried but proved of little help. Alkalinization of the urine with salts of lactic acid was also tried but was later abandoned as useless and dangerous; renal block prevented the desired effect, and serious alkalosis resulted. Peritoneal lavage was equally ineffective.

Miscellaneous complications.—Other complications, most of which were fatal, were recorded only occasionally. According to the clinical charts, urinary fistula occurred 6 times; fat embolism, 4 times; acute gastric dilatation, 3 times; and vesicorectal fistula, acute noncontagious parotitis, acute non-specific orchitis, encephalomalacia following ligation of the common carotid artery, meningitis secondary to spinal cord injury, cerebral infarct, anaphylactic shock following the use of intravenous protein hydrolysate, cachexia associated with ileostomy, and air embolism, in 1 case each.

CHAPTER XVI

Factors of Mortality

W. Philip Giddings, M. D., and Luther H. Wolff, M. D.

The most dreaded complication of abdominal wounds in World War I was sepsis, which usually took the form of peritonitis. Sepsis and hemorrhage were apparently the major causes of postoperative deaths in that conflict. Shock was not a prominent cause. When it is recalled, however, that in World War I patients were frequently selected for surgery according to their chances of survival, and that forward hospitals maintained so-called moribund wards¹ for the care and comfort of the hopelessly wounded, this is easily understood.

In this series of abdominal injuries sustained in World War II, postoperative sepsis caused only 91 deaths, 12.3 percent of the total number (table 33), and postoperative hemorrhage was not at all common. Shock, on the other hand, was a predominant cause of death, being responsible for 64.0 percent of all the fatalities. This is an index of the penalty paid, in terms of surgical mortality, for adherence to the policy of offering to every casualty the possible benefits of operation.

The lack of selection of patients for surgery (p. 87) inevitably led to a certain increase in the number of surgical deaths, especially during the induction of anesthesia and in the course of operation. In almost none of the 756 recorded fatalities, however, was it thought that surgery in itself had been responsible for the fatal outcome. On the contrary, in practically every fatal case the feeling was that death would surely have occurred if operation had not been undertaken. Moreover, a gratifyingly large number of even the most critically wounded men survived their injuries because they were operated on; they would certainly have died if surgery had been denied them. Many of them, although they were gravely ill for the first few days after operation, had, so far as is known, no disabling or crippling sequelae. Of the 3,154 casualties with abdominal wounds operated on by the 2d Auxiliary Surgical Group during 1944 and 1945, a very large number were saved from certain death by surgery, and most of them were left with no significant physical abnormalities.

It is important to emphasize again that the 756 deaths known to have occurred in this series are only those which occurred in *forward* hospitals, in which urgent initial surgery was performed and in which the usual postoperative stay was 8 to 14 days, with a range of 1 to 30 days. Additional deaths undoubtedly occurred in installations farther to the rear, though the exact number is not known, followup of these patients having proved impractical (p. 85).

¹ The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1, p. 451.

TABLE 33.—*Distribution of primary causes of death according to time of death in 737 abdominal injuries*¹

Cause	On operating table	Day of operation	Postoperative day												Total	Proportion of fatal cases	
			1st	2d	3d	4th	5th	6th	7th	8th	9th	10th	11th	12th and later			
Shock	83	208	118	3												472	64.0
Thoracopulmonary (all)	3	4	5	20	15	14	10	7	8	5	3				3	97	13.2
Peritonitis			6	20	13	10	10	6	7	5	4	4	1	5		91	12.3
Anuria				4	9	5	9	2	2	2	1		1			35	4.8
Anaerobic infection		1	1	2	3	1	1	2				1				12	1.6
Other		4	2	2	5	5	2	3	2			2		3		30	4.1
Total	86	277	132	51	45	35	32	20	19	12	8	7	2	11		737	100.0
Proportion (cumulative)	11.7	49.3	67.2	74.1	80.2	84.9	89.3	92.0	94.6	96.2	97.3	98.2	98.5	100.0			

¹ Nineteen cases in which the data on these points were incomplete are excluded from this table.

It is thought that an additional 2 percent (approximate) of the patients in the entire series of 3,154 cases died in forward hospitals but were unreported, and it should therefore be borne in mind that the rates cited throughout this report are actually somewhat lower than the true rates.

Although factors of mortality are discussed under various other headings throughout this report, it seems profitable to comment upon them again under a general heading.

GENERAL CONSIDERATIONS

Type of wound.—The gross case fatality rate for the 2,315 cases in this series in which the injuries were confined to the abdomen was 23.2 percent, and for the 839 thoracoabdominal injuries, 26.2 percent (table 6, p. 91). There was some improvement in the rates in both categories as the war progressed, more notably in thoracoabdominal injuries, as the result of the teaching and example of the thoracic surgical teams. In this type of wound, the case fatality rate fell from 28.2 percent in 1944 to 20.0 percent in 1945. The general improvement in the whole series can be explained on several valid grounds: (1) The increasing experience of the surgeons who cared for the casualties, (2) the advent of penicillin, and (3) the establishment of a theater blood bank.

Site of hospitals.—The discrepancy (table 5, p. 89) between the case fatality rate in field hospitals (24.3 percent) and in evacuation hospitals (15.1 percent) is readily explained by the fact that the farther forward a military hospital was located the greater was the number of severely wounded who survived to reach it and the more serious was their surgical risk. The significance of the multiplicity factor in this connection has been discussed elsewhere (p. 110). Among the men who died in field hospitals were many who were mortally wounded but who were operated on because of the theater policy, which was based on the conviction that surgery offered the best chance of survival to all casualties with abdominal wounds.

Age.—In the military-age group (roughly 20 to 40 years), there was a slight but steady rise in the case fatality rate as age increased, ranging from 20.5 percent in the first 5-year group to 26.9 percent in the last (table 34). Deaths before and after the military age period occurred, for the most part, in civilians, and the higher rates are to be explained by the unfavorable reaction of young children and aging persons both to injury and to subsequent surgery. Civilians were often brought to treatment late, and their physical state was generally poorer than that of American troops. The large group of patients whose age was not recorded and a large proportion of whom died consisted chiefly of civilians and prisoners of war, and the lack of data is explained by linguistic difficulties.

Shock.—The case fatality rate of these abdominal injuries was in proportion to the state of shock in which the patients were admitted (p. 121). It was 18.2 percent among patients not in shock or in minimal shock and 66.4 percent among those in profound shock (table 18, p. 121).

TABLE 34.—*Distribution of injuries and deaths according to age in 3,154 abdominal injuries*

Age (years)	Cases	Deaths	Case fatality rate
0 through 20.....	707	164	23. 2
21 through 25.....	987	202	20. 5
26 through 30.....	591	139	23. 5
31 through 35.....	250	60	24. 0
36 through 40.....	78	21	26. 9
Over 40.....	42	18	42. 9
Not stated.....	499	152	30. 5
Total.....	3, 154	756	24. 0

Season.—It was a repeated clinical observation that casualties received at field hospitals during the cold, wet winter months were likely to be in a more severe state of shock than men with comparable wounds during the summer months. Their poorer status was undoubtedly caused, at least in part, by exposure and by difficulties (and consequent slowing) of transportation. In addition, infectious pulmonary complications were almost a third more frequent in the winter, when chronic bronchitis and tracheitis seemed almost universal among frontline infantrymen (p. 204).

These circumstances were reflected in the difference in the case fatality rates for the winter months (October through March) and the summer months, which were, respectively, 27.4 and 19.9 percent (table 35). The casualties for August 1944 were lower in actual numbers than for any other month (fig. 15, p. 90), but the case fatality rate showed a rise. The explanation is that most of the injuries were incurred during the landings in southern France, when some delay in the establishment and operation of hospital facilities was in-

TABLE 35.—*Seasonal distribution of cases and deaths in 2,332 abdominal injuries (1944)*

Months	Cases	Deaths	Case fatality rate
January--March.....	430	141	32. 8
April--June.....	470	91	19. 4
July--September.....	503	103	20. 5
October--December.....	929	232	25. 0
Total.....	2, 332	567	24. 3

evitable. A sharper peak in the case fatality rate during February 1944 can be explained by similar difficulties in the early phase of the operation on the Anzio beachhead.

SPECIAL FACTORS OF MORTALITY

It has already been noted that when these 3,154 abdominal injuries were studied as a whole and the case fatality rate was plotted against the time interval from wounding to operation (timelag), the inimical effect of delay was surprisingly slight (fig. 20, p. 104). This was contrary to expectations and was not in accord with clinical observations.

The explanation was found in the multiplicity factor (p. 105). An analysis of cases from the standpoint of the number of organs injured revealed an almost arithmetical increase, of approximately 15 percent, in the case fatality rate with each additional viscus injured (fig. 21, p. 108). The rate rose from 7.5 percent when there was no visceral damage and 14.9 percent when only a single viscus was injured to 100 percent when 6 organs were injured.

When the cases were analyzed in exclusive categories from the joint standpoint of the multiplicity factor and the timelag (table 9, p. 106), it became apparent that the prognosis was gravely affected by a prolonged timelag. In univisceral injuries, the case fatality rate was 10.1 percent for the first 8 hours, 14.8 percent for the second, and 16.6 percent for the third. At the end of 36 hours, the rate was 26.4 percent. The cases in other categories of multiplicity followed essentially similar patterns of increase.

Superficially, the case fatality rate did not seem to be materially affected by the presence of coincidental extra-abdominal wounds. Here again, however, a different conclusion resulted when the multiplicity factor was taken into account. When the analysis was made from this standpoint, there was an average increase of approximately 3.9 percent in each category in the presence of associated wounds (fig. 23, p. 116).

Multiplicity of injuries was also found to influence the case fatality rate when the calculations were made on the type of organ injured (p. 95) and the particular organ injured (table 36). Rates for special organs are discussed in detail under the appropriate headings, but it should be emphasized here that the most reliable conclusions concerning the lethality of wounds of individual organs are obviously drawn from data relating to univisceral wounds. The type of organ injured definitely influenced the case fatality rate, univisceral injuries of hollow viscera being more lethal (17.4 percent) than those of solid viscera (11.1 percent).

It is unfortunate that figures are not available to permit detailed comparisons, on the basis of the number of viscera injured, of the abdominal injuries treated by the 2d Auxiliary Surgical Group and other recorded series. Such comparisons as are possible are presented in table 37.

TABLE 36.—Case fatality rates according to viscus wounded in 3,154 abdominal injuries

Organ injured	Univisceral wounds			Multivisceral wounds			Total		
	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate
Stomach.....	42	12	28.6	374	157	42.0	416	169	40.6
Duodenum.....	2	0	0	116	67	57.8	118	67	56.8
Jejuno-ileum.....	353	49	13.9	815	296	36.3	1,168	345	29.5
Colon only.....	251	57	22.7	816	329	40.3	1,067	386	36.2
Rectum only.....	64	9	14.1	52	18	34.6	116	27	23.3
Colon and rectum.....	13	6	46.2	26	14	53.8	39	20	51.3
Liver.....	339	33	9.7	490	191	39.0	829	224	27.0
Gallbladder.....	0	0	(¹)	53	16	30.2	53	16	30.2
Pancreas.....	1	1	100.0	61	34	55.7	62	35	56.5
Spleen.....	100	12	12.0	241	73	30.3	341	85	24.9
Kidney.....	56	9	16.1	371	146	39.4	427	155	36.3
Ureter.....	1	0	0	26	11	42.3	27	11	40.7
Bladder.....	21	0	0	134	46	34.3	155	46	29.7
Great vessels.....	8	5	62.5	67	50	74.6	75	55	73.3
Total.....	1,238	187	15.1	1,916	569	29.7	3,154	756	24.0

¹ Case fatality rate not applicable.TABLE 37.—Case fatality rates of visceral wounds in various recorded series of abdominal injuries ¹

Organ injured	Series	Cases	Deaths	Case fatality rate
Stomach.....	World War I, American.....	144	99	69
	World War II:			
	British.....	29	14	48
Duodenum.....	2d Auxiliary Surgical Group.....	416	169	41
	World War I, American.....	10	8	80
	World War II:			
Jejuno-ileum.....	British.....			
	2d Auxiliary Surgical Group.....	118	67	57
	World War I, American.....	272	205	75
Colon.....	World War II:			
	British.....	206	99	48
	2d Auxiliary Surgical Group.....	1,168	345	30
	World War I, American.....	222	171	77
	World War II:			
	British.....	160	86	54
	2d Auxiliary Surgical Group.....	1,106	406	37

¹ The rates listed are not strictly comparable, since the statistics for the 2d Auxiliary Surgical Group cover only forward hospitals. The American figures for World War I are from The Medical Department of the United States Army in the World War (Washington: U. S. Government Printing Office, 1927, see vol. XI, pt. 1, p. 65). The British figures are from the Western Desert combined series (628 cases) reported by W. H. Ogilvie in Abdominal Wounds in the Western Desert (see Surg., Gynec. & Obst. 78: 225-238, March 1944).

TABLE 37.—*Case fatality rates of visceral wounds in various recorded series of abdominal injuries—Continued*

Organ injured	Series	Cases	Deaths	Case fatality rate
Rectum.....	World War I, American.....	102	48	47
	World War II:			
	British.....	47	17	36
	2d Auxiliary Surgical Group.....	155	47	30
Liver.....	World War I, American.....	258	173	67
	World War II:			
	British.....	78	32	41
	2d Auxiliary Surgical Group.....	829	224	27
Gallbladder.....	World War I, American.....	11	7	64
	World War II:			
	British.....	5	1	20
	2d Auxiliary Surgical Group.....	53	16	30
Pancreas.....	World War I, American.....	4	4	100
	World War II:			
	British.....			
	2d Auxiliary Surgical Group.....	62	35	57
Spleen.....	World War I, American.....	51	34	67
	World War II:			
	British.....	32	16	50
	2d Auxiliary Surgical Group.....	341	85	25
Kidney.....	World War I, American.....	129	75	58
	World War II:			
	British.....	30	15	50
	2d Auxiliary Surgical Group.....	427	155	36
Ureter.....	World War I, American.....	4	2	50
	World War II:			
	British.....			
	2d Auxiliary Surgical Group.....	27	11	41
Bladder.....	World War I, American.....	125	67	54
	World War II:			
	British.....	24	10	42
	2d Auxiliary Surgical Group.....	155	46	30

TIME AND CAUSE OF DEATH

Three hundred and sixty-three of the 737 deaths in this series (49.3 percent) in which these data were available for analysis occurred on the day of operation (table 33). Eighty-six patients died on the operating table, four of them during the induction of anesthesia and the remainder during the procedure or within 10 minutes of its conclusion. The remaining 227 casualties in this group died within 24 hours after operation. Almost three-quarters of all the deaths occurred within 72 hours of operation. Thereafter, the number decreased with each succeeding day. The preponderance of fatalities during operation and within the immediate postoperative period is a clear index of the severity of the wounds.

The majority of deaths which occurred within 72 hours of operation were ascribed to shock, which accounted for 472 (64.0 percent) of the 737 deaths available for analysis from this standpoint. Included in this group of fatalities are 64 deaths in which the principal cause of shock was acute hemorrhage, as well as smaller numbers caused by shock attributable to severe peritoneal con-

tamination, cardiorespiratory embarrassment, cardiovascular injuries, severe cerebral injuries, blast injuries to the lungs, and other less common shock-producing injuries. In slightly more than half of these deaths, no single shock-producing factor could be identified. The fatality seemed to be caused by the interaction of hemorrhage, peritoneal contamination, and tissue destruction.

Thoracopulmonary complications, which were the cause of 13.2 percent of all deaths, consisted chiefly of pneumonitis, atelectasis, empyema, and pulmonary embolism. Their frequency was found to be related, at least in part, to the severity of the wound and the timelag, but their incidence rose in relation to the increasing multiplicity of visceral injuries (table 32, p. 206).

Peritonitis, which was responsible for 12.3 percent of all deaths, was most frequent in patients with an unusually prolonged timelag. This is what might be expected because the longer peritoneal contamination exists, the greater is the likelihood that a virulent peritonitis will develop. It should be emphasized again that the peritonitis responsible in this series for death after the third postoperative day was the type of bacterial process ordinarily seen in civilian practice, not the type caused by overwhelming contamination associated with shock and responsible for death soon after operation.

Anuria (lower nephron nephrosis, hemoglobinuric nephropathy), which was responsible for 4.8 percent of the deaths, does not seem to have been recognized as a clinical entity in World War I. It usually occurred in patients who were in severe shock when they were first seen, in whom resuscitation had been difficult, and who had required massive replacement therapy (p. 131). These fatalities seemed closely related to the fatalities which occurred earlier from shock. The patients escaped death, but at this time the physiologic changes which ultimately proved fatal were apparently established.

Miscellaneous causes of death, which accounted for 4.1 percent of the total number, included associated wounds and surgical and anesthetic complications. As individual causes of death, they cannot be said to have had more than a slight influence on the case fatality rate for the series as a whole.

ULTIMATE CAUSES OF DEATH

The case fatality rate in any series of injuries is a composite expression of the interaction of all the lethal factors in each individual case. By the classification of the 3,154 injuries of the abdomen treated by the 2d Auxiliary Surgical Group into exclusive categories, it has been possible to demonstrate that the most important factors in this series were apparently as follows:

1. The original severity of the wound, as it affected one organ or several. Though this was the most significant determinant of lethality in every case, it cannot be expressed graphically.

2. The number of organs injured. In the statistical analysis of this material, the clinical impression was immediately confirmed that the greater the number of organs injured, the higher was the case fatality rate. This factor is susceptible of statistical analysis.

3. The timelag, or the period from wounding to surgery. This factor, while it is susceptible to statistical analysis, is reliable only when it is related to the severity of the wound, expressed in terms of the number of viscera injured. The more severe the wound, the greater was the danger from a prolongation of the timelag and the graver was the prognosis.

4. The state of shock on admission. Almost three-quarters of all deaths in this series occurred within 72 hours after the patients were admitted to the hospital, and almost all of the fatalities in this group were attributable to shock. The more severe the state of shock, the graver was the prognosis.

In analyzing the factors of mortality in this series of abdominal injuries, it was immediately apparent, when the less frequent causes of death were excluded, that the most important lethal influence was the original severity of the wound. Since it was not possible to reduce severity to statistical terms, the most practical way to express it was in terms of the number of viscera injured; that is, the multiplicity factor, which is granted to be only an approximation. The second most important lethal factor was the timelag. The correlating factor between the multiplicity factor and the timelag was the degree of shock, which can be roughly defined as the manifestation of the effects of a wound of given severity affecting a casualty for a given length of time. Death caused by shock was the extreme manifestation of the combined effects of the multiplicity factor and the timelag.

The highest case fatality rates in this series occurred in two groups of patients: (1) Those who presented a high multiplicity factor, with injuries of four or more viscera, and (2) those admitted in severe shock. Actually, the two groups were usually one and the same because the greatest frequency of severe shock was observed in patients with the highest multiplicity factors. Patients with wounds of this kind were seldom seen after a prolonged timelag, for the reason that, if they did not reach the hospital promptly, they died before they could be brought to it.

A consideration of these facts leads to a conclusion quite in accord with clinical observations and also supported by the fact that approximately three-quarters of the deaths in forward surgical hospitals occurred within a relatively short period (72 hours) after operation. This conclusion is that the combined effects of a severe wound and of a prolonged timelag were likely to be lethal, regardless of the best resuscitative and surgical efforts.

CHAPTER XVII

Wounds of the Stomach (416 Casualties)

Luther H. Wolff, M. D.

An analysis of the 416 wounds of the stomach (table 38) which occurred in the 3,154 abdominal injuries treated by the 2d Auxiliary Surgical Group during 1944 and 1945 makes three points clear:

1. Wounds of this organ were considerably more frequent than they had heretofore appeared to be.

2. They were complicated by injuries to other viscera in 9 out of every 10 cases.

3. The case fatality rate in gastric injuries (40.6 percent) was significantly higher than it was in injuries of the colon, small intestine, liver, spleen, or genitourinary tract (q. v.).

TABLE 38.—*Essential data in 416 wounds of stomach*

Type of wound	Cases	Frequency		Deaths	Case fatality rate
		In 3,154 abdominal injuries	In 416 gastric injuries		
		<i>Percent</i>	<i>Percent</i>		
Univisceral.....	42	1.3	10.1	12	28.6
Multivisceral.....	374	11.9	89.9	157	42.0
Total.....	416	13.2	100.0	169	40.6

One hundred and ninety-six of these gastric injuries (47.1 percent) were produced by missiles which traversed the diaphragm. There were 85 deaths in these thoracoabdominal injuries (43.4 percent). In the remaining 220 cases, the projectiles entered or traversed only the abdominal cavity. There were 84 deaths in this group (38.2 percent).

In addition to the unexpectedly high frequency of injuries of the stomach in relation to total injuries in this series, the ratio of univisceral to multivisceral wounds is at marked variance with data reported in other series of abdominal wounds (table 39). The frequency was nearly twice as great as that previously reported. Actually, this is what might be expected. As has been pointed out (p. 92), the incidence of wounding of any organ is almost directly proportional to the space which it occupies. It follows, therefore, since the stomach

is a relatively large organ, that it would be injured fairly frequently. Furthermore, the frequency of wounding was probably even higher than is indicated by these figures, which take no account of casualties who died before reaching a field hospital.

TABLE 39.—*Comparative distribution of wounds of stomach in various recorded series of abdominal injuries*¹

Source	Total series	Wounds of stomach		Multivisceral wounds of stomach	
		Cases	Frequency (total series)	Cases	Frequency (wounds of stomach)
World War I:			<i>Percent</i>		<i>Percent</i>
American.....	(²)	144	7.0	48	33.3
British.....	965	82	8.5	26	31.7
Spanish Civil War.....	238	20	8.4	(²)	(²)
World War II:					
British ³	628	29	4.6	15	51.7
2d Auxiliary Surgical Group.....	3,154	416	13.2	374	89.9

¹ The American World War I figures are from the Medical Department of the United States Army in the World War (Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1, pp. 65, 457, 458). The British World War I figures were reported by Cuthbert Wallace in *War Surgery of the Abdomen* (London: J. & A. Churchill, 1918). The Spanish Civil War series was reported by Douglas W. Jolly in *Field Surgery in Total War* (New York: Paul B. Hoeber, Inc., 1941). The British World War II figures were reported by W. H. Ogilvie in *Abdominal Wounds in the Western Desert* (Surg., Gynec. & Obst., March 1944).

² Not stated.

³ Western Desert combined series.

The marked predominance of multivisceral over univisceral wounds is also what might be expected. Univisceral wounds are naturally infrequent in an organ almost completely invested by the liver, spleen, colon, and kidneys. It is believed that the figures for this series more nearly approach both the true frequency of wounds of the stomach and the true ratio of univisceral and multivisceral gastric injuries than any statistics previously reported, if only because in World War II more casualties survived to undergo surgery than in any previous war.

DIAGNOSTIC CONSIDERATIONS

Experience showed that only two signs could be regarded as conclusive in the preoperative diagnosis of a wound of the stomach. One was the emission of undigested food from an abdominal wound. The other was the actual observation of a perforation or laceration in an eviscerated stomach. In the absence of these two signs, the diagnosis was only presumptive.

According to the literature, vomiting is a cardinal sign of a wound of the stomach. An analysis of these 416 gastric wounds does not support this observation. Vomiting was no more frequent in wounds of the stomach than

in wounds of other abdominal viscera. It was actually recorded only 7 times in the 416 cases, and inquiry of resuscitation officers and of surgeons in the group revealed that none of them considered it an outstanding or a reliable sign of gastric injury.

Blood in the vomitus or in the aspirated gastric contents was, however, regarded as both suggestive and reliable. It was noted altogether in 41 wounds of the stomach (4 times in vomitus), and constituted a valuable clue to the nature of the injury when blood swallowed in wounds of the head, neck, or lungs could be ruled out. The absence of blood was not recorded consistently, being mentioned only eight times. The negative observation, even when it was recorded, was obviously of no diagnostic value.

The preoperative passage of a Levin tube, in the opinion of the surgeons of the group, not only did no harm in suspected wounds of the stomach but was, on the contrary, a useful diagnostic and therapeutic measure. The risk of introducing possible contamination to the injured site was far outweighed by the relief of the accumulations of gas and fluid which were common in gastric and other abdominal injuries and whose persistence led to increased leakage of gastric contents and more serious peritoneal contamination.

Leakage of gas from the damaged stomach was sometimes a valuable diagnostic sign, though it could also produce a variety of confusing but interesting clinical pictures. Thus subcutaneous emphysema of varying degrees was at times observed in the abdominal and chest walls, and in some instances gas actually bubbled from the abdominal wound. If the gastric wound were thoracoabdominal, gas from the stomach might escape into the pleural cavity through the lacerated diaphragm and produce pneumothorax.

Pneumoperitoneum was a matter of record in only six of the roentgenograms taken in wounds of the stomach. This is a deceptively low figure, since 90 percent of all casualties with abdominal wounds had preoperative roentgenographic examinations. The circumstances, however, were not conducive to precise roentgenography. All the examinations were made with portable apparatus. Practically always, as a concession to pain and shock, the patients were not moved from the supine position. Lateral views were impractical and were seldom attempted. Finally, conditions for both development and interpretation of the films were difficult. Under the circumstances, there is no doubt that a gas bubble lying free in the peritoneal cavity was sometimes overlooked.

In some cases, as soon as the peritoneum was opened, the surgeon was greeted by a rather disconcerting gush of air. It was often difficult to determine whether it originated in the stomach or from the chest, through a perforation of the diaphragm, and careful exploration was necessary to determine its origin. The presence of gas in the abdomen also introduced still another diagnostic problem—the possibility of an anaerobic infection. Crepitus and discoloration of tissues might be the result of gas and leakage of acid secretions from a perforation of the stomach, but it might also be explained by an early infection of this kind.

The preoperative diagnosis of a wound of the stomach depended chiefly on visualization of the course of the missile and the application of accurate anatomic knowledge concerning the location of the organ. In the great majority of these wounds, the location of the wounds of entry and exit—if the injury was perforating—and the location of the wound of entrance, combined with localization of the missile by two-plane roentgenography—if the injury was penetrating—permitted an accurate preoperative diagnosis.

Variations in the shape of the stomach and the position of the soldier at the time of wounding (p. 100) naturally complicated the diagnosis, as the following case history indicates:

Case 1.—A prisoner of war was seen in a field hospital with a wound of entrance in the left hip just above the head of the femur and a wound of exit in the right hip through the wing of the ilium. A low midline exploratory incision disclosed multiple perforations of the small bowel and sigmoid colon. It also, rather unexpectedly, disclosed a severe laceration of the stomach some 4 inches above the upper end of the midline incision. Reconstruction of the injury suggested that the stomach was in the lower abdomen at the time of wounding, the man undoubtedly being crouched over in the position a combat soldier automatically assumes when he is under fire.

NATURE OF THE INJURY

Wounds of the stomach varied widely in type (table 40). In 16 cases, the wound was a simple tangential laceration of the stomach wall, without penetration into the lumen. At the other extreme were 5 cases in which the violence of the trauma resulted in complete transection of the organ. In the remaining cases, the wound varied from a trivial perforation to a laceration 20 cm. long.

A fair proportion of the wounds were caused by small missiles, which perforated one or both walls of the stomach in a nearly perpendicular plane. Perforations of this kind often caused little or no peritoneal contamination from gastric leakage, since the redundant gastric mucosa tended to act as a valve and seal off the injury. Shock was not usually severe. A fairly large number of such injuries accounted for the relatively low case fatality rate in perforating wounds of the stomach (table 40). In contrast, missiles which entered the wall of the stomach at an acute angle were likely, regardless of their size, to produce

TABLE 40.—Case fatality rates in relation to type of injury in 416 wounds of stomach

Type of injury	Cases	Deaths	Case fatality rate
Perforating.....	258	91	35.3
Lacerating ¹	117	71	60.7
Not stated.....	41	7	17.1
Total.....	416	169	40.6

¹ Includes 5 complete transections.

extensive lacerations. Leakage was profuse, peritoneal contamination was severe, and the case fatality rate was correspondingly higher (table 40). Larger missiles tended to produce lacerating wounds, which were potentially more lethal, and part of the difference in the case fatality rates of perforating and lacerating wounds can be explained on this basis.

TIMELAG AND THE MULTIPLICITY FACTOR

As has already been mentioned (p. 217), the timelag was of the utmost importance in individual wounds of the viscera. In the whole series of 416 injuries, however, it did not seem of serious significance unless the analysis also took into account such other considerations as the multiplicity of visceral injuries, the number and character of associated injuries, and the degree of peritoneal contamination.

Univisceral wounds of the stomach (table 41) were so few (42, 10.1 percent) that their analysis from the standpoint of the timelag would be of no statistical importance. This is, also as already noted, a considerably lower frequency than is reported in any other comparable series. The case fatality rate, 28.6 percent, was surprisingly high. Although the multiplicity factor (p. 111) was found to be a more reliable prognostic index in abdominal injuries than any other factor, the general rule that the greater the number of organs injured, the higher the case fatality rate (fig. 21, p. 108) did not hold in wounds of the stomach in the first two multiplicity categories (table 41). It is true that in a category of only 42 univisceral wounds, statistical error is likely. On the other hand, an analysis of the 12 deaths in these 42 injuries seems to provide a clue to the lethality of a type of wound which in other structures was attended with a proportionately lower case fatality rate. This analysis showed that 7 of the 12 deaths in univisceral gastric injuries occurred either on the day of operation or within the first 2 days after operation, and that the cause was recorded in every instance as shock or shock and peritonitis. In two other cases, death occurred from peritonitis, one on the fourth and one on the eighth postoperative day. Another death was caused by peritonitis and a gastric fistula on the 15th postoperative

TABLE 41.—*Influence of multiplicity factor on case fatality rates in 416 wounds of stomach*

Organs injured	Cases	Deaths	Case fatality rate
Stomach only	42	12	28.6
Stomach and 1 viscus	174	47	27.0
Stomach and 2 viscera	112	44	39.3
Stomach and 3 viscera	50	29	58.0
Stomach and 4 viscera	23	23	100.0
Stomach, other viscera, and great vessels	15	14	93.3
Total	416	169	40.6

day. One of the two remaining deaths was caused by secondary hemorrhage from the stomach, on the 14th postoperative day. In the other case, no cause of death was stated. These are small figures and of no statistical significance, but a clinician cannot fail to be impressed by the causes and time of death and by the number attributed to shock.

In multivisceral injuries (table 42), the liver, as might be expected, was most frequently involved, with the colon and the spleen next in order. Concomitant injury to the colon produced the highest case fatality rate except for concomitant injuries to the great vessels. The latter were almost universally fatal (table 41).

One extremely significant fact in the analysis of these multivisceral wounds was the discovery that treatment had been successful in certain combinations of wounds which up to this time had been uniformly fatal. Bailey,¹ for instance, stated in 1942 that in the past no combination of wounds involving the stomach, small intestine, and colon had ever been successfully treated. In the 24 injuries of this kind in this series, in 11 of which the liver was also injured, there were 15 survivals.

TABLE 42.—Case fatality rates in wounds of stomach complicated by wounds of other viscera¹

Organs injured	Cases	Deaths	Case fatality rate
Stomach only.....	42	12	28.6
Stomach and liver.....	67	20	29.9
Stomach and spleen.....	42	8	19.0
Stomach and colon.....	24	11	45.8
Stomach, colon, and liver.....	18	9	50.0
Stomach, liver, and spleen.....	17	5	29.4
Stomach and jejunum.....	16	4	25.0
Stomach, jejunum, and colon.....	13	4	30.8
Stomach, jejunum, colon, and liver.....	11	5	45.5
Stomach and kidney.....	10	3	30.0
Stomach, jejunum, and liver.....	9	3	33.3
Stomach and ileum.....	7	0	0
Stomach, colon, and spleen.....	6	2	33.3
Stomach, jejunum, and kidney.....	6	2	33.3
Stomach, spleen, and kidney.....	6	2	33.3
Stomach and pancreas.....	6	1	16.7
Stomach, colon, and kidney.....	5	5	100.0
Stomach, colon, liver, and spleen.....	5	2	40.0
Stomach, liver, and pancreas.....	5	1	20.0

¹ This table does not include combinations of visceral wounds which occurred less than 5 times each. It also does not include 2 injuries of the stomach and duodenum in which both patients survived and 2 injuries of the stomach and great vessels in which both patients died.

¹ Bailey, Hamilton: *Surgery of Modern Warfare*. Edinburgh: E. & S. Livingstone, 1941-42.

ASSOCIATED INJURIES

About a quarter of the 416 casualties with wounds of the stomach also had severe extra-abdominal injuries. Forty-three presented major fractures, forty-one major soft-tissue injuries, nine major amputations, nine injuries of the spinal cord, four injuries of the brain, and four injuries of the heart. The chest injuries present in thoracoabdominal wounds were, strictly speaking, separate associated lesions, and their presence apparently produced a 5-percent increase in the case fatality rate in this group. An evaluation of the effect of the associated injury and its influence on morbidity and case fatality rates would require a case-by-case analysis. Generally speaking, the rate among patients with associated injuries did not differ significantly from that of patients without them, though the fallacy of the application of such a generalization to the individual case is obvious.

TECHNICAL CONSIDERATIONS

The transdiaphragmatic approach to wounds of the fundus and body of the stomach (table 43) greatly facilitated the repair of injuries in these areas, both the anterior and posterior surfaces of the fundus being accessible through the incision without opening of the peritoneal folds. It is, therefore, not surprising that this incision was used in 119 (60 percent) of the 196 thoracoabdominal injuries. Eventually, it became the incision of choice in selected cases, though it was used in only one instance in which there was not a perforation of the diaphragm. In that type of injury, a vertical incision in the upper abdomen was preferred.

The gastrocolic omentum was incised routinely at operation, to permit examination of the posterior gastric wall. Whether operation was done from above or from below the diaphragm, this was a most important step of the procedure in patients known or suspected to have sustained gastric injuries.

TABLE 43.—*Distribution of surgical approaches in 412 wounds of stomach*¹

Approach	Cases	Percentage
Laparotomy.....	293	71.1
Transdiaphragmatic:		
Thoracotomy.....	95	23.1
Combined laparotomy and thoracotomy.....	18	4.4
Thoracolaparotomy ²	6	1.4
Total.....	119	28.9
Grand total.....	412	100.0

¹ Information is lacking on this point in four cases.

² By this technique, the thoracic incision is extended across the costal arch onto the abdominal wall.

Simple suture, which was used in 409 of the 416 injuries of the stomach, was regarded as the procedure of choice, even in extensive lacerations. Resection was required in the five cases in which transection of the stomach was complete. The Polya or Hofmeister technique was used in three cases, all of which were fatal, and end-to-end anastomosis in the other two, one of which was fatal.

Perforations of the stomach were overlooked at operation in the two remaining cases in the series. One of the patients died of a gastropleural fistula; the other died of embolism. At autopsy, the overlooked perforations were discovered; they had closed spontaneously, without apparent leakage, and had not contributed to the fatal outcome.

The type of suture closure, as well as the kind of suture material, varied with the preference of the individual surgeon. Except that purse-string suture proved unsatisfactory, as will be pointed out shortly, variations in technique seemed to make no difference in the outcome of the case.

In six cases, all simple perforations, severe postoperative hemorrhage occurred from the stomach. This was the largest number of postoperative hemorrhages encountered in the entire series of 3,154 abdominal injuries. Three patients died. Two survived under conservative management, and the other recovered uneventfully after a secondary operation to control bleeding.

It is significant that in all six instances of postoperative bleeding, closure had been by reinforced purse-string suture. This method can produce circumstances ideal for the development of hemorrhage. Since the suture seldom, if ever, includes the gastric mucosa, the mucosal edges retract. As a result, the blood vessels which traverse the submucosa are exposed, and the resulting pathologic picture simulates that of acute peptic ulceration. Erosion of the previously sealed underlying vessels, and subsequent hemorrhage, are therefore possibilities whenever this method is used. The following case history illustrates this fact:

Case 2.—A soldier with multiple wounds from shell fragments, including a left thoraco-abdominal wound, was admitted to a field hospital in excellent general condition. Trans-diaphragmatic repair of a single perforation of the upper portion of the stomach was carried out by means of a purse-string suture through a left thoracotomy incision. The operation was performed without complications, and convalescence was smooth until the fifth post-operative day, when evidences of internal bleeding were observed. When laparotomy was resorted to, after 7 hours of conservative therapy, the stomach was found to be completely occupied by a clot estimated to contain 1,500 cc. of blood. After the clot had been removed, the site of perforation and suture was inspected from the mucosal side. The surgeon's notes adequately explained the hemorrhage: "A white indurated area is seen from which the mucosa is retracted. From the edges, in two places, are seen continuous but small streams of blood, one venous and the other arterial. This ulcer-like area, then, is the cause of all bleeding." Excision of the affected area and closure of the wound were followed by an uneventful recovery.

This report and others like it led to certain technical changes:

1. Every effort was made to approximate the gastric mucosa by suture in all wounds of the stomach.

2. Small perforations were enlarged transversely so that the mucosal layer could be exposed and accurately sutured.
3. Purse-string suture was no longer employed in wounds of the stomach.

POSTOPERATIVE COMPLICATIONS

As already noted, practically every patient who died within the first 48 hours after operation as the result of a wound of the stomach presented the clinical picture designated under the generic term "shock." All had sustained extensive tissue damage, massive blood loss, disturbed pulmonary physiology, peritoneal contamination of varying degrees, or combinations of these conditions. Persistent shock resulting from these conditions is, strictly speaking, a postoperative complication, but it is not classified as such in this discussion because of the time of its occurrence. Actually, it was part of the original pathologic process.

Of the complications which occurred later than 48 hours after operation, by far the commonest were pulmonary. In fact, pneumonia (12 cases), empyema (11 cases), and atelectasis (6 cases) accounted for approximately 40 percent of the serious complications seen after this time. Peritonitis was observed in 6 cases, 5 of which were fatal. In all instances, it was of the usual clinical (bacterial) type.

CASE FATALITY RATE

The data analyzed in this section bear out the initial statement that wounds of the stomach, whether univisceral or multivisceral, are among the most serious injuries encountered in warfare (table 44). Some perforations were comparatively trivial, but the leakage of acid gastric contents into the general peritoneal cavity was always serious and was likely to be associated with a high degree of shock. In general, patients with wounds of the stomach exhibited a much more severe degree of shock than those with other abdominal wounds. In 22 cases (13 percent of the fatalities) death occurred on the operating table; death occurred in the course of operation in only 11 percent of all other fatalities in the total series of abdominal injuries. The 115 fatalities (68 percent of the total deaths from wounds of the stomach) which occurred by the end of the second postoperative day were chiefly attributable to shock alone or in association with peritonitis and, to a lesser degree, other complications, or to overwhelming peritoneal contamination.

In 12 of the 416 casualties with wounds of the stomach, the records contributed nothing concerning the presence or absence of shock. In 66 other cases, the patients were either in no shock at all or in incipient shock. One hundred and three of the remaining patients were in mild shock, one hundred and six in moderate shock, and one hundred and twenty-nine in severe shock. The unusually high proportion of casualties in moderate and severe shock can be explained, at least in part, by the spillage of acid gastric contents into the

general peritoneal cavity. There seems no doubt that whenever spillage of such contents occurred, an immediate chemical peritonitis ensued, which quickly produced either shock or a shocklike state and which was entirely different from the bacterial peritonitis observed in later stages of the injury in patients who survived.

TABLE 44.—*Primary cause of death in relation to time of death in 169 wounds of stomach*

Time and cause of death	Cases
On operating table:	
Shock.....	13
Shock and hemorrhage.....	5
Shock and atelectasis.....	1
Shock and gas gangrene.....	1
Shock and peritonitis (contamination).....	1
Cardiac.....	1
Total.....	22
Through second postoperative day:	
Shock.....	43
Shock and peritonitis (contamination).....	28
Shock and hemorrhage.....	4
Shock and atelectasis.....	3
Shock and anaerobic infection.....	2
Peritonitis (massive contamination).....	9
Peritonitis (massive contamination) and pneumonia.....	2
Peritonitis (massive contamination) and intestinal fistula.....	1
Pulmonary embolism.....	1
Total.....	93
After second postoperative day:	
Peritonitis (bacterial).....	5
Peritonitis (bacterial) and shock (all third day).....	8
Peritonitis (bacterial) and pneumonia, empyema, or pleurisy.....	12
Anuria.....	10
Pneumonia.....	6
Hemorrhage, secondary.....	3
Pneumothorax and pleurisy.....	3
Intestinal or gastric fistula.....	2
Brain injury.....	1
Not stated.....	4
Total.....	54

Another possible explanation of shock in wounds of the stomach originates in anatomic considerations, that the stomach overlies a highly vascularized area in which are located the celiac axis, the aorta, the inferior vena cava, and

the portal vein, and that massive hemorrhage is therefore frequently associated. Although this is theoretically sound reasoning, hemorrhage in gastric wounds did not appear to be more severe than in numerous other visceral wounds in this series. The part which it played in the production of shock was often difficult to evaluate, it is true, but in the usual wound of the stomach it seemed to be secondary in importance to peritoneal contamination.

After the second postoperative day, peritonitis and pulmonary complications were the most important causes of death (table 44). The case fatality rate among casualties with lacerating wounds was almost double that among those with perforating wounds (table 40), the explanation probably being that all patients with lacerating wounds suffered massive peritoneal flooding with acid stomach contents, which presumably happened in a much smaller proportion of those with perforating wounds. The high case fatality rate among patients with univisceral wounds of the stomach (table 41) is further proof of this hypothesis. Although the relative vascularity of the stomach and the adjacent structures theoretically should play a part in the lethality of gastric wounds, the collective clinical observations of the 2d Auxiliary Surgical Group did not support this point of view.

CHAPTER XVIII

Wounds of the Duodenum (118 Casualties)

W. Herschel Cave, M. D.

The figures from World War I indicate that wounds of the small intestine are among the most lethal encountered in warfare. Wallace, who reported 363 cases in 985 abdominal injuries in British soldiers, recorded a case fatality rate of 65.9 percent for uncomplicated (univisceral) injuries and of 74.1 percent for complicated (multivisceral) injuries.¹ The case fatality rate for American troops was between 70 and 80 percent.² That modern surgical measures and efficient adjunct therapy have greatly improved the chances of survival in this group of casualties is evident from the figures reported for World War II.

Wounds of the duodenum are infrequent. They accounted for only 6 percent of all injuries of the small bowel recorded among American soldiers in World War I,³ and there were only 16 (4.4 percent) in Wallace's ⁴ series of 363 small-bowel injuries. The 118 wounds of the duodenum observed by the 2d Auxiliary Surgical Group in 1944-45 (table 45) represent only 3.7 percent of the 3,154 abdominal injuries treated by the group during that period.

TABLE 45.—*Essential data in 118 wounds of duodenum*

Type of wound	Cases	Frequency		Deaths	Case fatality rate
		In 3,154 abdominal injuries	In 118 duodenal injuries		
		<i>Percent</i>	<i>Percent</i>		
Univisceral.....	2	0.1	1.7	0	0
Multivisceral.....	116	3.6	98.3	67	57.8
Total.....	118	3.7	100.0	67	56.8

Wounds of the duodenum are almost never univisceral. In this series, other organs were injured in 116 of the 118 cases (table 45), while all 9 duodenal injuries observed in 1943 were multivisceral and were, like the 1944-45 cases, characterized by the variability of the organs involved.

¹ Wallace, Cuthbert: *War Surgery of the Abdomen*. London: J. & A. Churchill, 1918.

² The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1, pp. 65, 459-460.

³ *Ibid.*

⁴ See footnote 1.

DIAGNOSTIC CONSIDERATIONS

The preoperative diagnosis of injuries of the duodenum was made principally on the basis of probability. As experience with the pattern of the injury increased, it could readily be deduced that a missile entering the right side of the abdomen or the right lumbar region was likely to injure not only the liver, the colon, and the right kidney, but also the duodenum. It therefore became routine, when the abdomen was opened for an injury in these regions, to reflect the right colon and examine the duodenum thoroughly. The results of increasing consciousness of the possibility of injury of the duodenum are seen in the fact that while 2 perforations of the duodenum were overlooked in the 9 duodenal injuries treated by the 2d Auxiliary Surgical Group in 1943, only 1 was overlooked in the 118 cases treated in 1944-45. Other visceral injuries in this series of duodenal injuries included 69 of the liver, 59 of the colon, and 37 of the right kidney.

NATURE OF THE INJURY

The site of the wound of entry was fairly constant in these injuries of the duodenum (fig. 27) and suggested the diagnostic pattern which has just been described. In 96 instances, 81.4 percent, the missile entered the right side of the trunk from the front or the back.

In the 112 wounds in which the details were stated (table 46), the second portion of the duodenum was injured in 49.1 percent, the first portion in 24.1 percent, and the third in 13.4 percent. In the remaining cases, more than one portion was injured. In many injuries of the first portion, the lesion was continuous with a wound of the pylorus, and several injuries of the third portion, similarly, were continuous with wounds of the jejunum. The predominance of injuries of the second portion of the duodenum suggests that many casualties with injuries of the first portion did not survive to reach the hospital because of simultaneous fatal injuries of such close-lying structures as the vena cava, the hepatic artery, and the portal vein. Similar reasoning can be applied to explain the small number of injuries of the third portion; there is a close anatomic relationship between the duodenum and the aorta, the vena cava, and the mesenteric vessels.

Although the majority of the duodenal wounds were perforating or lacerating (table 46), there were 20 instances of transection in the series. In one instance, the injury was attributed to indirect violence. The patient presented a large gutter wound across the epigastrium, through which omentum had herniated. No wound of exit was found, nor was a foreign body demonstrable by roentgenology. The stellate lacerations of the liver and the second portion of the duodenum discovered at laparotomy were assumed by the surgeon to have been caused by concussion.

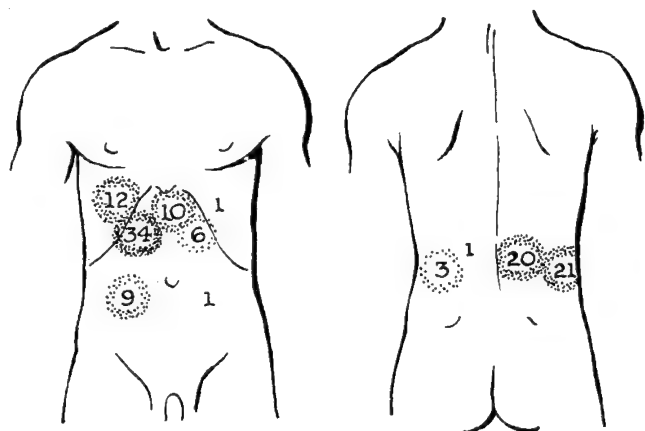


FIGURE 27.—Sites of wounds of entry in 118 injuries of duodenum.

TABLE 46.—Site and type of injury in 112 wounds of duodenum

Site of injury	Perforation	Laceration	Transection	Total
First portion.....	12	8	7	27
Second portion.....	34	14	7	55
Third portion.....	6	8	1	15
Junction of first and second portions.....	2	4	—	6
Junction of second and third portions.....	2	2	1	5
Duodenojejunal junction.....	—	—	4	4
Total.....	56	36	20	112

TECHNICAL CONSIDERATIONS

Lacerations and perforations of the duodenum were usually repaired by a standard, fairly uniform technique. Transections were repaired by end-to-end anastomosis with running sutures of atraumatic chromic catgut, usually reinforced with silk or cotton sutures. The peritoneum, as a rule, was closed over the wound. The site of repair was drained in almost every case, and drainage was mandatory if the pancreas or the liver was also wounded. In the four cases in which gastrojejunostomy was necessary (all of which were promptly fatal), the damage to the duodenum was extensive and beyond repair.

POSTOPERATIVE COMPLICATIONS

Two fistulas of the duodenum are known to have developed in the field hospitals in which these 118 duodenal injuries were treated. Both occurred on the sixth postoperative day, and both in cases in which transections of the

duodenum had been repaired by end-to-end anastomosis with chromic catgut reinforced by silk. The figures are too small to be significant, but it may be that there is a tendency for fistulas to develop after transection of the duodenum. Drainage following repair, therefore, seems indicated in all injuries of this type.

In another instance, it was assumed that fistula developed. The injury was a simple laceration of the second portion of the duodenum, which had been repaired by a single running suture of atraumatic chromic catgut reinforced with interrupted silk sutures. The clear, irritating discharge which began to issue from the wound on the sixth day was regarded as duodenal in origin.

TIME AND CAUSES OF DEATH

Sixty-seven of the one hundred and eighteen patients with duodenal injuries (56.8 percent) are known to have died in forward hospitals within the first 10 days after operation. In two additional cases, it is believed that death also occurred within this period, though the records are too incomplete to permit a positive statement. These figures are to be compared with the World War I American Army figures, which show 8 fatalities in the 10 recorded instances of duodenal injury.⁵ In 47 of the 67 fatalities (table 47), death occurred within the first 3 days after operation.

TABLE 47.—Primary cause of death and time of death in 67 injuries of duodenum

Cause of death	Time of death				Total
	On operating table	First 24 hours	24 to 72 hours	4th to 10th days, inclusive	
Shock and hemorrhage.....	5	25	8	1	39
Pneumonia.....			2	7	9
Anuria.....			2	6	8
Transfusion reaction.....			2		2
Pulmonary embolism.....			1		1
Peritonitis.....				3	3
No record.....			2	3	5
Total.....	5	25	17	20	67

Shock and hemorrhage were recorded as the cause of 39 of the fatalities, 58.2 percent (table 47). The patients who did not survive were, on the whole, in a more severe state of shock when they were hospitalized than were those who survived (table 48). Two of the three deaths attributed to peritonitis occurred in cases in which visceral injuries had been overlooked at operation;

⁵ See footnote 2, p. 235.

one was a laceration of the common bile duct and the other a perforation of the third portion of the duodenum.

Of the 20 patients who sustained transections of the duodenum, 14 died within the first 6 days after operation. The other six are known to have survived beyond this period. In one instance, in which autopsy was not performed, it was thought that the duodenal suture had given way. The patient had sustained a through-and-through perforation of the upper pole of the right kidney, which had been drained, and a through-and-through perforation of the second portion of the duodenum, which had been closed with two layers of running sutures of atraumatic chromic catgut. He became greatly distended on the seventh postoperative day and complained of severe epigastric pain; death occurred 8 hours later.

TABLE 48.—*Influence of degree of shock on case fatality rates in 114 wounds of duodenum*

Degree of shock	Cases	Deaths	Case fatality rate
None.....	20	6	30.0
Mild.....	15	3	20.0
Moderate.....	20	8	40.0
Severe.....	59	50	84.7
Total.....	114	67	58.8

Multivisceral wounds, as already noted, were the rule in duodenal injuries (table 49), being present in all but two instances in this series. Both patients with univisceral injuries survived. The factor of multiplicity greatly increased the lethality of wounds of the duodenum. The major surgery required in multivisceral wounds played an important part in the increase in the case fatality rates. The rate was 57.0 percent in the 21 cases in which nephrectomy was done, 75.0 percent in the 8 cases of cholecystectomy, 70.0 percent in the 13 small-bowel resections, 77.7 percent in the 9 cases of colectomy, and 80.0 percent in the 5 cases of splenectomy.

Wounds of the large blood vessels played a particularly important part in the high case fatality rate of duodenal injuries. Of the 9 patients who had lacerations of the vena cava, 8 died; the only survivor was not in shock when he was first seen. Death also occurred in the 2 injuries of the portal vein, the 2 injuries to the pancreaticoduodenal artery, and the injuries of the hepatic and the right spermatic artery (1 each).

Pancreatic injuries were also highly fatal; death occurred in 8 of the 9 cases, though in only 1 instance was the head of the pancreas so badly damaged that the duct was severed.

TABLE 49.—*Influence of multiplicity factor on case fatality rates in 118 wounds of duodenum*

Organs wounded	Cases	Deaths	Case fatality rate
Duodenum only.....	2	0	0
Duodenum and 1 viscus ¹	28	16	57.1
Duodenum and 2 viscera.....	45	20	44.4
Duodenum and 3 viscera.....	21	14	66.7
Duodenum and 4 viscera.....	20	15	75.0
Duodenum and 5 viscera.....	2	2	100.0

¹ One fatality in this category was a univisceral wound, complicated by a wound of the portal vein, which was primarily responsible for the fatal outcome.

In 15 of the 118 duodenal injuries, an associated chest injury was present, varying in severity from a simple perforation of the diaphragm to severe lacerations or contusions of the lung. Eleven of these fifteen patients died.

CHAPTER XIX

Wounds of the Jejunum and Ileum (1,168 Casualties)

W. Philip Giddings, M. D., and John R. McDaniel, M. D.

Between 1 January 1944 and 8 May 1945, the surgeons of the 2d Auxiliary Surgical Group treated 1,168 casualties with injuries of the jejunum and ileum, of whom 345 (29.5 percent) died (table 50). These 1,168 injuries represent 37.0 percent of the 3,154 abdominal injuries observed over the period of time stated.

TABLE 50.—*Essential data in 1,168 wounds of jejunum and ileum*

Type of wound	Cases	Frequency		Deaths	Case fatality rate
		In 3,154 abdominal injuries	In 1,168 jejuno-ileal injuries		
		<i>Percent</i>	<i>Percent</i>		
Univisceral.....	353	11. 2	30. 2	49	13. 9
Multivisceral.....	815	25. 8	69. 8	296	36. 3
Total.....	1, 168	37. 0	100. 0	345	29. 5

NATURE OF INJURY

Included in these injuries of the jejunum and ileum are six in which the abdominal wall was not penetrated. All were incurred in vehicular accidents and all resulted in rupture of the small bowel. Another patient, who sustained a severe transfixing thoracoabdominal wound, was injured when he was impaled on the stump of a small tree by the blast of an exploding shell. With these seven exceptions, all the wounds in the series were caused by high-explosive fragments or missiles from small arms. There were no bayonet or stab wounds.

The lesions varied from pinpoint perforations and small contusions to extreme maceration and destruction of the greater portion of both ileum and jejunum. For convenience of discussion, the injuries have been classified under four headings: (1) Injury to the intestinal wall, (2) injury to the mesentery, (3) perforating injury, and (4) transections (table 51). Wide extremes of severity were noted in each group, and as a rule 2 or even 3 lesions were seen in combination.

TABLE 51.—*Frequency of various types of injury in 1,168 wounds of jejunum-ileum*

Injury	Cases	Injuries	Average frequency per case
Injury to intestinal wall.....	27	31	1
Injury to mesentery ¹	30	30	1
Perforation ²	1, 083	4, 589	4
Transection.....	213	361	2

¹ Severe enough to require resection.

² The arbitrary figure of 5 was used when perforations were recorded as "multiple," without statement of the precise number. Whenever the precise number was recorded, it was used.

Injury to the intestinal wall.—Trauma to the intestinal wall included contusions and lacerations of the serosal or seromuscular coats which did not perforate the mucosa. This type of injury was not frequent (table 51). Contusions, which were seldom more than 2 cm. in diameter, varied from areas of slight ecchymosis to circumscribed areas of gangrene. A contusion of the bowel wall implied, by its very nature, that the missile which had caused it had reached the end of its flight and was traveling at such low velocity that its impact against the intestine was sufficient to stop it. In this type of injury, the missile either was embedded in the wall of the bowel or lay free in the peritoneal cavity.

Lacerations of the intestinal wall were caused by tangential impact, and no inferences are, therefore, permissible concerning the velocity of the causative missile. They usually occurred in association with perforations of the lumen in other portions of the bowel. Theoretically, a laceration might be of any length. Practically, in the absence of a perforation, it was seldom more than 2 cm. long. Some lacerations were merely breaks in the serosa. Usually there were evidences of contusion about the margins of a laceration, and the laceration-contusion type of injury was considered a potential site for future perforation.

Injury to the mesentery.—Injuries of the mesentery occurred both at the mesenteric attachment and at a considerable distance from the bowel. They varied from small hematomas or peritoneal lacerations to rents which extended across the mesentery to its root. Some damage to the adjacent mesentery nearly always occurred in transections of the bowel and in perforations involving the mesenteric border. Bleeding had usually ceased when the casualty was first seen, but in some instances bleeding was still active.

Perforations of the mesentery other than those adjacent to injuries of the bowel were frequent. They were usually simple through-and-through holes. Hematomas were sometimes present also, but in the majority of cases there was no indication that a vessel of major consequence was involved. The incidence of mesenteric damage sufficiently extensive to necessitate intestinal resection was remarkably low; in all 1,168 injuries of the jejunum and ileum there were only 30 cases in which resection was required because of vascular impairment

from mesenteric injury. The circumstances of this type of injury, including the effects of energy transmitted to the tissues and the natural tendency to clot formation in a lacerated blood vessel, would be expected to produce thrombosis. Thrombi were commonly found protruding from the ends of severed vessels in the mesentery, even when the vessels were of considerable size, but the thrombotic process was invariably restricted to the immediate area of damage. There was no instance in the series of extensive mesenteric thrombosis (in the usual clinical sense of the term) in which the pathologic process could be regarded as caused primarily by trauma to the mesentery.

Perforating trauma of the intestine.—By far the commonest type of injury to the small intestine was perforation into the lumen. This occurred in 1,083 of the 1,168 injuries, and multiplicity was the rule, the average number of perforations per case being four (table 51).

Small perforations occasionally seemed to have been caused by indriven fragments of bone, especially when the missile had entered the abdomen through the ilium. Generally speaking, the size and shape of the rent in the bowel were determined by the corresponding characteristics of the missile, as well as by its velocity and the direction of its flight. Through-and-through perforations and complete transections were both frequent.

Under some conditions of injury, isolated perforations might be found at a considerable distance from the major trauma, though as a rule multiple injuries were in close proximity to each other, and damage was ordinarily confined to a segment 1 or 2 feet in length, or even less. These phenomena were explained by the fact that in the usual case, intestinal damage was caused by a single missile, the effect of which was confined to its line of flight. Scattered perforations were caused by missiles which traversed major diameters of the abdomen; by separate missiles with different wounds of entry; or by multiple fragments which, though they entered through a common wound, pursued divergent courses within the abdomen.

Individual lesions varied from tiny holes to gashes 6 inches or more in length. When the perforations were of any size, the findings were similar. The tissues about the edges were contused and ecchymotic. The margins were jagged. Mucosa usually pouted from the wound. Bleeding from the intestinal wall was sometimes free, and considerable amounts of blood were seen in the peritoneal cavity when the bowel wall was the only apparent source of hemorrhage. Small perforations were sometimes almost completely sealed off by pouting mucosa, so that there was a minimum of soiling of the cavity. In such cases, there was a bluish discoloration of the bowel, from intraluminal bleeding. Less commonly, blood and intestinal contents were extensively spilled from small perforations, as in the following case:

Case 1.¹—A 29-year-old infantryman was wounded by a machinegun bullet which entered the left lower abdomen. The ilium was fractured at the wound of entrance and the greater trochanter of the left femur was fractured at the wound of exit. When the patient was

¹ This case appears in table 54 as case 18.

admitted to a field hospital 20 hours later, he was in severe shock and was anoxic and disoriented.

Operation was performed 23.5 hours after wounding, after the administration of 1 unit of plasma and 5 pints of blood. Although the injury was limited to a single small perforation of the jejunum, which was readily repaired by suture, a generalized, fulminating peritonitis was already present, and the surgeon noted on the operating sheet that the spillage of intestinal contents was the most extensive he had ever seen.

After operation, the patient remained extremely toxic. Oliguria developed and progressed to anuria. Death occurred on the eighth postoperative day. Post mortem examination revealed an acute, fibrinopurulent generalized peritonitis, with a right-sided subphrenic abscess.

Transection.—Transections of the intestine, which were fairly common (table 51), represented the extreme form of perforations of the jejunum and ileum. The most characteristic feature of these injuries was that they were nearly always accompanied by extensive spillage.

State of the peritoneum.—The small bowel is well vascularized, and the frequency of hemoperitoneum in injuries of the jejunum and ileum was consistent with that fact. In some instances, 2,000 cc. of blood, or more, were in the peritoneal cavity, usually as the result of massive bleeding from the mesentery. At the other extreme, bleeding was occasionally minimal.

The peritoneal cavity was usually contaminated to some degree with contents of the small bowel, though in an occasional case no gross soiling was apparent. The degree of contamination was usually compatible with the size and number of the perforations. The peritoneal reaction was fairly constant in relation to the time at which surgery was undertaken. When operation was performed within 6 hours of injury, there was usually no visible reaction. Violent exudative peritonitis was the rule only in patients seen after a relatively long timelag (12 hours or more). In casualties who survived longer than 24 hours without operation, early walling off of the perforation with loops of adherent bowel was likely to have occurred. These findings, of course, were not invariable. Severe generalized peritonitis was sometimes seen in patients treated early, and localization was also occasionally seen in early cases. Definitive peritonitis was recorded at operation in only 50 of the 353 univisceral wounds of the jejuno-ileum, a figure which is undoubtedly too low.

Evisceration.—Evisceration of the jejunum and ileum occurred in 153 instances in the whole series of 3,154 abdominal injuries. Trauma to the involved bowel or its mesentery required repair in 126 cases. In the remaining cases, evisceration was incidental and required no treatment other than reduction. In only one instance was resection necessary because of strangulation of the eviscerated loop.

Associated injuries.—Two hundred and fifty-two of the 1,168 casualties with injuries of the jejunum and ileum had major associated peripheral wounds, and 202 had minor associated wounds. Another 143 casualties had penetrating or perforating wounds of the thorax, of which 94 (8.0 percent of all injuries of the jejuno-ileum) were thoracoabdominal. About half (597) of all the casual-

ties with injuries of this portion of the small bowel thus had associated wounds, about two-thirds of which (395) were of a major character.

DIAGNOSIS

The preoperative diagnosis of wounds of the jejunum and ileum was made chiefly on probabilities. There were no criteria by which their existence could be established or excluded before operation. Indriven fragments of bone and the concussive effect of missiles passing extraperitoneally were known to cause perforation or rupture, and whenever these circumstances were present it was not regarded as safe to assume that the bowel had not been injured. Diagnosis, therefore, was usually established or, occasionally, disproved by exploration of every case in which the circumstances of wounding and the clinical signs and symptoms indicated possible intra-abdominal injury.

PREOPERATIVE ROUTINE

The preoperative management of wounds of the small intestine differed in no respect from the preoperative management of other abdominal injuries. An essential part of the routine was the introduction of a Levin tube into the stomach, followed by aspiration of the gastric contents.

TREATMENT

Certain general principles were universally followed in the management of wounds of the jejunum and ileum. These included nontraumatic handling of all tissues, maximum protection of the bowel from exposure, the use of fine suture material, and as rapid operation as was consistent with thorough exploration and necessary repair procedures. In many instances, the control of hemorrhage and operations on other viscera took precedence over the repair of the small-bowel lesions. Time was always saved by a preliminary evaluation of the total damage. About a third of the surgeons in the group thought it expedient, in the investigation of possible damage to the small bowel, to bring it out through the surgical incision and examine it outside of the abdomen. Complete examination of the jejuno-ileum and its mesentery was facilitated by this technique, and those who practiced it felt that, if it were carried out gently and expeditiously, it was not shocking to the patient. Its use was limited to cases in which the damage was obviously extensive and the lesions were obscured by some degree of spillage.

Contusions and lacerations of the intestinal wall were repaired and reinforced by a peritonealizing linear or purse-string suture, of whatever material the individual surgeon might prefer. With this exception, the type of repair was related to the type of injury.

Simple through-and-through perforations of the mesentery were sutured, to reperitonealize the raw surfaces, but dissection was carried out in the presence of large hematomas or continuing bleeding. After the hematoma had been

evacuated and hemorrhage controlled, the mesentery was closed by suture. As already mentioned, intestinal resection because of mesenteric vascular damage was required in only 30 cases in the series. In these patients, the usual criteria of viability of the bowel were observed, and resection was performed in accordance with recognized surgical principles.

A wide variety of techniques was used in the repair of perforating lesions of the bowel. The basic principle of management was to select the most conservative procedure compatible with secure repair and preservation of an adequate lumen. Very small perforations were usually closed by purse-string suture. Larger perforations were sutured transversely. Debridement of the traumatized edges was frequently omitted. If it was regarded as necessary, it was as conservative as possible. It was sometimes found convenient to convert two perforations into a single lesion, particularly if they were located close together in the same vertical plane. The single defect which resulted could be sutured in less time than was required to suture two separate perforations, and in the end there was less kinking of the bowel.

Resection and anastomosis.—The indications for resection (tables 52 and 53) were usually clear cut. It was clearly mandatory when segments of the bowel were hopelessly macerated. It was also required when the bowel had been avulsed from its mesentery. Multiple adjacent perforations separated by areas of intact bowel always presented problems. Under these circumstances, some surgeons repaired each perforation separately. Others, if the involved segment was not too long, resected it in toto, fearing that multiple suture lines so close together might compromise the lumen and lead to intestinal obstruction from kinking.

TABLE 52.—Comparative results of anastomotic and suture repair in 1,117 wounds of jejunum-ileum¹

Type of injury	Total series			Anastomosis ²				Suture			
	Cases	Deaths	Case fatality rate	Cases	Frequency	Deaths	Case fatality rate	Cases	Frequency	Deaths	Case fatality rate
Univisceral.....	348	47	13.5	135	Percent 38.8	25	18.5	213	Percent 61.2	22	10.3
Multivisceral.....	769	281	36.5	347	45.1	155	44.7	422	54.9	126	29.9
Total.....	1,117	328	29.4	482	43.2	180	37.3	635	56.8	148	23.3

¹ Omitted from this table are nonperforating injuries and all injuries in which ileocolostomy was the only treatment.

² In 54 cases, anastomosis was performed without resection.

Various techniques of anastomosis were employed (table 53). The majority of surgeons preferred an open, two-layer, end-to-end method whenever it was practical. Closed methods were used when soiling was minimal. A few surgeons routinely employed the closed silk technique. Side-to-side anastomosis was usually reserved for injuries of the lower ileum or for cases in which, after extensive resection, there was marked discrepancy in the size of the lumens to be

TABLE 53.—*Comparative case fatality rates of resection with various techniques of anastomosis in 428 injuries of the jejunum-ileum*

Technique of anastomosis	Cases	Frequency	Deaths	Case fatality rate
		<i>Percent</i>		
End-to-end.....	377	88.1	120	31.8
Side-to-side.....	34	7.9	16	47.1
Not recorded.....	17	4.0	9	52.9
Total.....	428	100.0	145	33.9

anastomosed. Two surgeons reported successful results with a single-layer type of anastomosis. Two others preferred triple layers. Running or interrupted sutures of catgut and interrupted sutures of fine silk or cotton were widely used. As a general rule, the same type of suture and the same suture material employed for anastomosis were also used for the repair of perforations.

Four hundred and twenty-eight patients were subjected to 466 resections, which included 35 double resections with 13 deaths (37.1 percent) and 3 triple resections with 2 deaths. The case fatality rate of 47.1 percent (table 53) for the 34 side-to-side anastomoses is a reflection of the severity of the trauma in the cases in which it was used, rather than an index of the risk of this technique. It was unusually employed only in massive resections.

In the 394 cases in which data on this point were available, the length of the resected segments ranged from 2 inches to 12 feet. In 272 cases, the length was between 2 and 12 inches. In the other 122 cases, it averaged 34 inches. In 4 cases, segments more than 8 feet in length were resected. The case fatality rate in the 122 cases in which the resected segments measured 12 inches and more in length was 35.2 percent (43 deaths), which is in close agreement with the case fatality rate of 33.9 percent for all resections (table 53).

The case fatality rate of resection in injuries of the jejunum-ileum (33.9 percent) was higher than the rate of repair by suture (23.3 percent). The rate for anastomosis without resection (54 cases, 35 deaths, 64.8 percent) was very considerably higher. The ratio of the case fatality rate of repair by anastomosis to repair by suture was 1.79 in univisceral cases (18.5 and 10.3 percent respectively) and 1.50 in multivisceral cases (44.7 and 29.9 percent, respectively). In other words, anastomotic repair carried a higher case fatality rate than suture repair in both groups of cases, and of approximately the same order in each. The multiplicity factor furnishes no explanation of these figures, since the case fatality rate of anastomosis was higher in univisceral cases.

The results in this series therefore confirm the general impression that anastomotic repair of the small bowel is more hazardous than repair by suture, regardless of the circumstances under which it is employed. On the other hand, the principal indication for intestinal resection in this series was always extensive

trauma. The procedure was usually undertaken only when the bowel was in shreds and beyond hope of conservative repair. The higher case fatality rate for this procedure is therefore probably as much a reflection of the severity of the injury as of the relative risks of suture repair and intestinal resection.

The following case histories are presented as typical:

Case 2.—A medical corpsman was brought into a field hospital about 2 hours after he had sustained a severe penetrating gunshot wound of the left abdomen, with an extensive evisceration of small intestine through a large defect in the abdominal wall. He was in severe shock, and neither blood pressure nor pulse could be obtained. After 2,500 cc. of blood had been administered as rapidly as possible, the blood pressure rose to 52/40 mm. Hg and the pulse became perceptible, though it still could not be counted.

Laparotomy was performed 3 hours after wounding. The root of the mesentery was found avulsed, this injury being the source of massive, persistent bleeding. The missile had perforated the left mesocolon and lay in the lumbar musculature. There were multiple lacerations and transections of the ileum and jejunum, and because of vascular impairment it was necessary to resect 10 feet of small intestine. Several perforations of the jejunum were also sutured. The patient's condition began to improve as soon as hemorrhage had been controlled, and by the end of the operation the blood pressure was 104/60 mm. Hg. A transfusion of 500 cc. of whole blood was given on the operating table.

Recovery was uneventful. The Levin tube was removed on the sixth day, and on the same day the patient has a spontaneous bowel movement. He was evacuated in good condition on the 13th postoperative day. A month later, it was learned that his improvement had continued and that he was about to be evacuated to the Zone of Interior.

Case 3.²—An 18-year-old German prisoner of war was admitted to a field hospital about 20 hours after he had sustained a penetrating wound of the abdomen from a shell fragment. He was in severe shock that did not respond to vigorous resuscitation therapy. Operation was undertaken about 24 hours after wounding. The peritoneal cavity was extensively contaminated with small-bowel content and was the site of a plastic peritonitis. The color of the bowel was unhealthy, and it was seriously mangled in three separate areas. A total of 3 feet was resected in three segmental procedures, and several other perforations were repaired by suture. End-to-end anastomoses were performed, the highest about 4 inches below the ligament of Treitz.

The man's condition became progressively worse during operation, in spite of continuous transfusions of whole blood, and death occurred about 5 minutes after the abdomen had been closed.

Case 4.—A 42-year-old artilleryman, wounded by a shell fragment which penetrated the abdomen through the left lower quadrant, arrived at a field hospital in good condition. He was immediately given 500 cc. of blood. Roentgenologic examination disclosed a metallic foreign body in the right lower quadrant of the abdomen. Operation, performed 8 hours after wounding, revealed "multiple perforations of very large size" in the small bowel. Resection of three separate intestinal loops, with end-to-end anastomosis, was performed in the jejunum and in the upper and the lower ileum. The large shell fragment visualized in the roentgenogram was removed from the wall of the ileum.

The postoperative course was entirely uneventful. The patient was in good condition and was taking liquids by mouth when he was evacuated on the eighth postoperative day.

Enterostomy.—Enterostomy was employed only twice in the initial management of these 1,168 injuries of the jejunum and ileum. In the first instance, a small perforation at the ileocecal junction was managed by tube ileocecostomy, the procedure being selected because of the peculiar anatomic site of the injury. The history of the second patient follows:

² This case appears in table 54 as case 9.

Case 5.—A German prisoner of war was admitted to a field hospital 3 days after he had been wounded by a shell fragment which had penetrated the right lower quadrant of the abdomen. His condition, except for dehydration, appeared good. There was tenderness in the right lower quadrant of the abdomen, and a thin, watery discharge exuded from the wound in this area.

At operation, the wound was converted, by lengthening it, into a modified gridiron incision. A large abscess cavity anterior to the cecum contained a perforated loop of ileum, and tube ileostomy was performed through the perforation. Convalescence was fairly smooth, but undigested food particles were observed in the discharge from the ileostomy. A note was made that the perforation was probably higher in the intestine than it had seemed to be at operation and that an attempt at closure might have been preferable to enterostomy. The patient was evacuated on the 10th postoperative day. This case represents 1 of the 9 instances of fistula formation in the series (p. 251).

Management of the contaminated peritoneal cavity.—Two surgeons in the group routinely placed drains to the peritoneal space in the presence of contamination, whether from the small bowel or from other sources. The remainder were opposed to drainage of the cavity. A very few surgeons believed that lavage of a severely contaminated peritoneal cavity prior to closure of the abdomen aided in the removal of gross material which could not be evacuated by other means, but this method was used too infrequently to permit an evaluation of either its efficacy or its possible risks.

According to the records, sulfanilamide crystals or penicillin sodium were used intraperitoneally, alone or in combination, in 59 percent of the injuries of the jejunum and ileum. The actual figure is thought to be higher. Whether or not they were used in this manner rested with the individual surgeon. No opinion was arrived at concerning the efficacy of intraperitoneal chemotherapy and antibiotic therapy in injuries of the small intestine.

POSTOPERATIVE COMPLICATIONS

The recorded complications of injuries of the jejunum and ileum during the time the patients were under observation in forward hospitals were extraordinarily few. It is unlikely that serious complications were not recorded. On the other hand, the figures are perhaps not really representative, since complications undoubtedly developed in many cases after evacuation.

Ileus, distention, and vomiting apparently were almost universal among patients with abdominal injuries in World War I. In World War II, the routine use of nasogastric decompression practically eliminated these dangerous postoperative complications. Patients with injuries of the jejunum and ileum were intubated with the Levin tube prior to surgery, and three-bottle siphonage suction was instituted as soon as they reached the postoperative ward. The tube was left in place for from 3 to 8 days after operation. Considerable differences of opinion existed as to how long decompression was required after operation, but most surgeons favored a period of 3 to 6 days. Removal of the tube was determined by the standard clinical criterion; namely, return of intestinal function as manifested by audible peristalsis, the passage of flatus

and similar phenomena. After the tube had been removed, oral nutrition was cautiously increased in accordance with the patient's ability to tolerate food.

The Miller-Abbott tube, although it was always readily available, was only occasionally used in the management of jejuno-ileal injuries. It was the consensus of the surgeons of the group that there were few indications for intubation of the intestine since in most instances adequate decompression could be obtained by the Levin tube. This was fortunate, for in the few cases in which the Miller-Abbott tube was used it was difficult, under field conditions, to get it past the pylorus.

Routine postoperative care prevented the development of most other complications. Careful attention was given to the maintenance of the fluid and electrolyte balance, to the hematocrit level, and to nutrition. Patients were usually kept in Fowler's position until peritonitis had definitely subsided.

Intestinal obstruction.—Of the 1,168 patients with injuries of the jejunum and ileum, 20 (1.7 percent) presented symptoms of mechanical intestinal obstruction while they were still in forward hospitals. Ten had sustained severe multivisceral wounds; peritonitis had been present at operation in two cases; and gross contamination of the cavity had been recorded in six others. Five of the twenty patients had undergone suture repair, four anastomosis without resection, and eleven resection and anastomosis. One patient had had a double resection, and two others had had resections as well as simple anastomoses or transections. In 10 of the 15 cases in which anastomosis was performed, suture repair was also necessary for other injuries.

Obstructive symptoms, in the 17 cases in which these data were recorded, appeared between the 3d and the 32d day after operation. If the 2 cases are omitted in which symptoms became apparent on the 32d day, the average time of appearance of symptoms is lowered to between the 6th and 7th days.

Seven of the twenty patients died (35.0 percent). In the six instances in which necropsy was carried out, the cause of the obstruction was found to be adhesions in three cases, and kinking of the anastomosis, edema at the anastomosis, and leakage from the anastomosis with subsequent peritonitis in one case each. In the single fatality in which autopsy was not performed, death followed development of a small intestinal fistula which was attributed to leakage at an anastomosis.

The method of management of the obstruction was mentioned in only 1 of the 7 fatal cases. In this instance, although the Miller-Abbott tube did not pass the pylorus, decompression of the obstructed bowel was successful, and death was caused by severe atypical pneumonia and hepatitis of unknown etiology. It seems safe to assume that conservative measures were also employed in the other fatal cases; had operation been performed, it would certainly have been recorded.

Ten of the thirteen patients who survived were treated conservatively, reinstitution of nasogastric decompression being the principal therapeutic measure. Data are not available concerning the length of time it was required.

The other (three) patients were operated on when conservative therapy proved unsuccessful. In one case, obstruction was the result of adhesions, in one of adhesions complicated by multiple abscesses, and in one of adhesions complicated by volvulus of the ileum.

Intestinal leakage and fistula formation.—Leakage from the small bowel occurred in 12 cases after operation and was followed in 9 instances by fistula formation. In 6 of the 12 cases, there were severe wounds of other hollow viscera. In the 8 cases in which these data were recorded, the complication developed between the 6th and the 26th postoperative days, the average time being 13 days.³

As always, leakage from the small bowel proved a serious matter. It was fatal in all 3 cases in which fistula formation did not occur, and in 2 other cases in which fistulas developed. In 4 of the 5 fatalities, death was attributed to peritonitis; the cause was not stated in the fifth case. In each of the three autopsied cases, leakage was found to have occurred at a suture line, and it seems reasonable to assume that the same accident happened in the two other fatal cases. In 1 of the 3 autopsied cases, 2 perforations of the terminal ileum resulted from erosion of the intestine by the through-and-through wire sutures used to repair a wound disruption on the 9th postoperative day; the patient died of peritonitis on the 22d day. Data are not available concerning the origin of the leakage in the two other autopsied cases.

Secondary surgery for closure of fistulas was not performed in forward hospitals. The patients were evacuated as promptly as possible to general hospitals, where facilities for prolonged special care were available.

UNIVISCERAL WOUNDS

The 353 univisceral injuries in this series (table 50) include, as already mentioned (p. 241), 2 nonbattle injuries. The other 351 casualties were all wounded by high-explosive fragments or by bullets. The ileum was injured more frequently (180 cases) than the jejunum (128 cases), the ratio being roughly 3:2. Both portions of the bowel were injured simultaneously 45 times, which is only about a quarter as frequently as the ileum was wounded alone.

The case fatality rate for the 353 univisceral injuries (table 50) was 13.9 percent. The rate for wounds of the jejunum alone (13 deaths) and of the ileum alone (23 deaths) was approximately the same, 10.2 and 12.8 percent, respectively. The case fatality rate rose sharply to 28.9 percent (13 deaths) when both portions of the bowel were involved. The increase is readily explained by the fact that many of the injuries represented extensive trauma to a large segment of the midbowel and required massive resection.

The average timelag from injury to operation in the recorded fatal cases of univisceral injury of the jejuno-ileum was twice that in the recorded nonfatal

³ Attention is called elsewhere (p. 249) to the additional case of fistula formation observed in a German prisoner of war, who had an established fistula of the small bowel and an intraperitoneal abscess when he was admitted to a field hospital 3 days after wounding.

cases, being 9.5 hours in 293 nonfatal cases and 19.1 hours in 46 fatal cases. If 2 cases in which the timelag was unusually prolonged (72 hours and 90 hours, respectively) are omitted, the figure for the fatal cases is reduced to 16.3 hours. The timelag for all 339 (recorded) univisceral injuries was 10.9 hours, which is essentially the same as the lag (10.6 hours) for the 1,057 cases in the whole series of jejuno-ileal injuries in which these data are available. If all patients with this type of injury could have been operated on within 8 hours of wounding, their chances of recovery would probably have been greatly enhanced.

A disproportionately large number of severe associated injuries apparently contributed to the case fatality rate of univisceral wounds of the jejunum and ileum. Associated injuries were more than twice as frequent among the fatal as among the nonfatal cases. They were recorded in 72 (23.7 percent) of the 304 patients with univisceral injuries who survived and in 27 (55.1 percent) of the 49 patients who died. They included serious compound fractures of the long bones, traumatic amputations of extremities, penetrating wounds of the thorax other than thoracoabdominal wounds, severe cranial injuries, severe maxillofacial injuries, and soft-tissue wounds which either were extensive or were associated with severe hemorrhage.

At least 3 of the 49 fatalities in univisceral wounds of the jejunum and ileum can be justifiably attributed to these associated injuries. One man with a wound of the heart died on the operating table from cardiac tamponade. Another, who had also sustained a blast injury of the lungs, died 5 hours after operation. The third died from hemolytic streptococcic bacteriemia and pyemia following infection of a massive wound of the thigh. In all three cases, the diagnosis was established at autopsy.

In 15 other cases, death apparently was the result of the combined effects of intestinal and associated wounds, both of which were severe, as the following representative case history indicates:

Case 6.—An infantry man was brought into a field hospital in severe shock 20 hours after he had sustained an extensive shell-fragment wound of the right buttock. Operation was performed 4 hours later, after he had received 3,000 cc. of blood. Two small perforations of the ileum were sutured at laparotomy, which revealed an extensive early fibrinous peritonitis.

It proved impossible to control the extensive phagedenic infection which developed in the wound of the buttock and which ultimately involved the entire gluteal muscle group and the lumbar and posterior thigh muscles also. The patient became oliguric and uremic and died on the fifth day after operation, his course having been continuously downhill. At autopsy, the peritoneal cavity was found clean and free of infection, and infection and necrosis in the thigh and buttock were reported to be the chief causes of death.

If the 18 cases in which death was attributable wholly or in part to associated wounds are excluded from this discussion and if only the 31 fatalities in which the intestinal injury played the major role (table 54) are considered, a more accurate impression can be obtained of the causes of death in cases in which injury of the jejunum and ileum was the primarily fatal factor. Shock or peritonitis was listed as the chief cause in 15 patients who survived operation

for periods of time varying from 5 minutes to 48 hours. These cases fell into the well-defined group of casualties, seen in forward hospitals, who were admitted to the field hospitals in the severe shock which seemed, in part at least, to be secondary to massive peritoneal contamination (p. 127). The timelag was usually long, associated hemorrhage was frequent, and death occurred promptly.

Peritonitis was listed as the primary cause of death in 8 patients who survived operation for periods varying from 3 to 22 days. Peritoneal infection could not be controlled in these cases, but the element of persisting shock, which was present in the patients who died promptly after operation, was no part of the picture.

TABLE 54.—*Causes of death in 31 primarily fatal injuries of jejunum-ileum*

Case	Time-lag	Site of injury	Postoperative survival	Cause of death
	<i>Hours</i>			
1	8.0	Jejunum-ileum.....	36 hours.....	Peritonitis; shock.
2	19.0	Ileum.....	2 days.....	Generalized peritonitis, severe; pulmonary edema, severe.
3	17.0	Jejunum.....	2 hours.....	Shock; peritonitis.
4	12.0	Jejunum-ileum.....	24 hours.....	Shock.
5	20.0	do.....	2 days.....	Do.
6	38.0	Jejunum.....	36 hours.....	Shock; severe mesenteric hemorrhage.
7	27.0	Ileum.....	9 hours.....	Generalized fibrinopurulent peritonitis (present at operation).
8	36.0	do.....	5 hours.....	Shock; peritonitis.
9	22.0	Jejunum-ileum.....	5 minutes.....	Do.
10		do.....	5 hours.....	Shock.
11	13.0	Jejunum.....	24 hours.....	Shock; peritonitis.
12	48.0	Ileum.....	6.5 hours.....	Do.
13	11.5	Jejunum-ileum.....	24 hours.....	Generalized peritonitis.
14	37.0	do.....	14 hours.....	Shock; peritonitis.
15	10.0	do.....	24 hours.....	Generalized peritonitis; shock.
16	90.0	Jejunum.....	4 days.....	Generalized peritonitis.
17	14.5	Ileum.....	5 days.....	Suppurative, generalized peritonitis, severe; mesenteric thrombosis lower third ileum.
18	23.5	Jejunum.....	8 days.....	Acute fibrinopurulent peritonitis, severe; anuria; uremia.
19	14.0	Jejunum-ileum.....	22 days.....	Generalized and localized peritonitis; 2 perforations ileum caused by wire sutures.
20	6.0	Ileum.....	3 days.....	Peritonitis.
21	15.0	do.....	11 days.....	Do.
22	7.0	Jejunum-ileum.....	12 days.....	Generalized peritonitis; bronchopneumonia.
23	4.0	Ileum.....	8 days.....	Generalized and localized purulent peritonitis; leakage at anastomosis.
24	10.0	do.....	5 days.....	Intestinal obstruction; kinked anastomosis.
25	7.0	do.....	10 days.....	Massive pulmonary embolism.
26	16.0	Jejunum-ileum.....	5 days.....	Oliguria; anuria; uremia.
27	6.5	Jejunum.....	3 days.....	Diffuse purulent tracheobronchitis.
28	6.5	do.....	13 days.....	Hepatitis; atypical pneumonia; intestinal obstruction.
29	5.5	Ileum.....	10 minutes.....	Aspiration of vomitus.
30	4.0	do.....	1 day.....	Cardiorespiratory death, unexplained clinically or at autopsy.
31		Jejunum-ileum.....	5 days.....	Not recorded.

¹ Autopsy.

The incidence of peritonitis recorded at operation is not considered reliable because many of the operative notes were incomplete. It is of interest, however, that it was specifically mentioned as being present in 41 percent of the patients who died, as contrasted with only 10 percent of those who survived.

One death was attributed to intestinal obstruction. In one case, no cause of death was stated. In the six remaining cases, the fatalities were attributed to causes not inherently related to wounds of the small intestine, such as pulmonary embolism and anuria.

In the fatal univisceral wounds, therefore, about half of the patients died in the immediate postoperative period of shock and overwhelming peritoneal contamination. About a quarter died later of peritonitis. The remainder, except for the patient who died of intestinal obstruction, died of unpredictable and unrelated complications. The outstanding causes of death in patients who died primarily of univisceral injuries to the jejunum and ileum were shock, severe peritoneal contamination, prolonged timelag, and peritonitis. Interaction among these factors was often observed clinically. Apparently they were mutually complementary, and they cannot be completely divorced from each other for the purpose of statistical analysis.

CHAPTER XX

Wounds of the Colon and Rectum (1,222 Casualties)

C. Frank Chunn, M. D., and Richard V. Hauver, M. D.

In the 3,154 casualties with abdominal wounds treated by surgical teams of the 2d Auxiliary Surgical Group between 1 January 1944 and 8 May 1945, there were 1,222 with wounds of the colon, rectum, or both. These injuries are in addition to the 136 similar injuries treated between April and December 1943. The case fatality rate in the 1943 series was 42.6 percent (58 deaths), as compared with 35.4 percent (433 deaths) in the cases managed in 1944 and 1945. The essential data in the 1944-45 cases are set forth in table 55.

TABLE 55.—*Essential data in 1,222 wounds of colon and rectum*

Type of wound	Cases	Frequency		Deaths	Case fatality rate
		In 3,154 abdominal injuries	In 1,222 colon-rectum injuries		
		<i>Percent</i>	<i>Percent</i>		
Colon only.....	1,067	33.8	87.3	386	36.2
Univisceral.....	251	7.9	20.5	57	22.7
Multivisceral.....	816	25.9	66.8	329	40.3
Rectum only.....	116	3.7	9.5	27	23.3
Univisceral.....	64	2.0	5.2	9	14.1
Multivisceral.....	52	1.7	4.3	18	34.6
Colon and rectum.....	39	1.23	3.2	20	51.3
Univisceral.....	13	.41	1.1	6	46.2
Multivisceral.....	26	.82	2.1	14	53.8
Total.....	1,222	38.7	100.0	433	35.4
Univisceral.....	328	10.41	26.8	72	21.9
Multivisceral.....	894	28.32	73.2	361	40.4

As in all other groups in this series, the 1,005 patients with wounds of the colon and rectum for whom these data were available were chiefly (63.0 percent) in the age range 20 to 40 years. The case fatality rate was essentially the same for this age group (33.8 percent) as for the group from infancy to 20 years (32.4 percent), although the latter group includes civilian children who had a rate somewhat above the average. The 22 casualties over 40 years of age, 10 of whom died, were chiefly civilians.

NATURE OF THE LESION

Wounds of the colon were caused by the same agents, which were implicated with approximately the same frequency, as all other abdominal wounds (p. 92). The series does not include serous and seromuscular lacerations without perforation into the lumen. There were only a few of these injuries, and they resulted chiefly in minor bruises or subserosal hematomas. The series is made up entirely of perforations, transections, and other severe injuries to the large bowel, including injuries which resulted in interruption of the blood supply. The perforations, as in injuries of other portions of the bowel, ranged from small holes without leakage to injuries which completely destroyed large segments of the bowel and were associated with massive fecal spillage.

Contamination of the retroperitoneal space from a perforation of the extraperitoneal colon was common and always presented a formidable complication, particularly in extensive wounds of the right colon. Fecal matter was spread widely and forcibly through severely damaged muscle and areolar tissue. Adequate debridement often required extensive excision of the lumbar and iliopsoas muscles, and satisfactory surgery was often performed with difficulty because of extensive hematoma formation and the close proximity of important anatomic structures, notably the ureter and the great vessels of the pelvis. Identification of retroperitoneal structures and the control of hemorrhage were frequently time consuming and of great technical difficulty.

Of the 1,358 wounds of the colon treated in the 1943-45 period, 191 were thoracoabdominal (table 56).

TABLE 56.—*Case fatality rates in 191 thoracoabdominal injuries involving the colon*¹

Site of intestinal injury	Cases	Deaths	Case fatality rate
Ascending colon.....	13	9	69.2
Hepatic flexure.....	22	15	68.2
Transverse colon.....	76	33	43.4
Splenic flexure.....	57	30	52.6
Descending colon.....	23	8	34.8
Total.....	191	95	49.7

¹ These injuries occurred in the 1,358 wounds of the large bowel treated in 1943-45.

TIMELAG AND THE MULTIPLICITY FACTOR

The average lapsed time from wounding to operation in the 1,222 wounds of the colon and rectum in this series was 10.9 hours, the interval being essentially the same for both fatal and nonfatal cases.¹ It is to be compared with

¹ It will be noted that in this chapter there are apparently no cases in which data concerning timelag are lacking. There are two explanations: (1) The authors of the chapter made a special effort to check all nonrecord cases with the operating surgeons and were often able to secure approximate time intervals from them. (2) When they could not secure these data, as well as in cases in which investigation of the missing data was not possible, they adopted the plan of using for their calculations the average timelag of all cases treated by the teams which handled these cases.

the average time interval of 10.5 hours recorded for all 3,154 cases in the total series, as well as with the interval of 11.3 hours reported for all abdominal injuries in 1943. The average time spent in resuscitation in the hospital before operation was undertaken was 3 hours, which makes the interval from wounding to hospitalization between 7 and 8 hours. In more than a quarter of all cases (27.5 percent), operation was begun within 6 hours of injury, and in almost three-quarters of the cases (74.5 percent) it was begun within 12 hours.

A tendency toward an increase in the case fatality rate in wounds of the colon (table 57) was apparent through the 18-hour period. It ceased after this interval. In later categories, the figures available for analysis were too small to permit conclusions.

The case fatality rates in relation to the timelag between wounding and operation must be interpreted in the light of two considerations:

1. While in general the patient's chances were improved the shorter the interval between wounding and surgery, account must also be taken of the influence of the multiplicity factor (table 58).

2. The case fatality rate in patients operated on within 12 hours of wounding (320 of 911 patients, table 57) was kept to 35.1 percent, in spite of the fact that this group included the casualties who were critically and often mortally wounded and who often reached the hospital alive only because of rapidity of evacuation.

TABLE 57.—*Influence of timelag on case fatality rates in 1,222 wounds of colon and rectum*

Timelag	All cases			Colon only			Rectum only			Colon and rectum		
	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate
0 to 6 hours.....	336	105	31.3	314	96	30.6	15	5	33.3	7	4	57.1
To 12 hours	575	215	37.4	497	192	38.6	57	12	21.1	21	11	52.4
To 18 hours	168	65	38.7	139	55	39.6	23	7	30.4	6	3	50.0
To 24 hours	66	20	30.3	51	18	35.3	11	1	9.1	4	1	25.0
To 48 hours	65	25	38.5	54	22	40.7	10	2	20.0	1	1	100.0
48 hours or more....	12	3	25.0	12	3	25.0						
Total.....	1,222	433	35.4	1,067	386	36.2	116	27	23.3	39	20	51.3

Injuries of the colon were accompanied by injuries of 1 or more other viscera (table 58) in approximately 3 out of every 4 cases (74.7 percent). Injuries of the rectum were accompanied by injuries of other viscera in more than half of all cases (58.7 percent). In both portions of the large bowel, wounds of additional viscera caused an increase in the case fatality rate, the increase being directly proportional to the number of viscera affected. Injuries of both solid and hollow viscera caused an increase in the case fatality rate in about the same proportion. In the 552 wounds of the colon in which hollow viscera were also injured, there were 205 deaths (37.1 percent); and in

TABLE 58.—*Influence of combined timelag and multiplicity factor on case fatality rates in 1,155 injuries of colon and rectum*

Injury	0 to 6 hours			To 12 hours			To 18 hours			To 24 hours			Over 24 hours			Total		
	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate
Colon or rectum only	71	9	12.7	120	26	21.7	38	6	15.8	25	4	16.0	38	12	31.6	292	57	19.5
Colon and 1 viscus	159	45	28.3	242	79	32.6	79	32	40.5	25	6	24.0	28	10	35.7	533	172	32.3
Colon and 2 viscera	67	31	46.3	110	53	48.2	34	17	50.0	14	6	42.9	8	5	62.5	233	112	48.1
Colon and 3 viscera	25	14	56.0	31	12	38.7	7	6	85.7	5	4	80.0	2	1	50.0	70	37	52.9
Colon and 4 viscera	7	6	85.7	13	10	76.9	1	1	100.0	—	—	—	1	1	100.0	22	18	81.8
Colon and 5 viscera	1	1	100.0	4	4	100.0	—	—	—	—	—	—	—	—	—	5	5	100.0
Total	330	106	32.1	520	184	35.4	159	62	39.0	69	20	29.0	77	29	37.7	1,155	401	34.7
Multiplicity index	2.22			2.21			2.08			1.99			1.70					

the 161 wounds in which solid viscera were also injured, there were 55 deaths (34.2 percent).

In addition to the complicating visceral injuries just discussed, damage to a major blood vessel of the abdomen was a complication in 25 cases, 23 of which terminated fatally. In 8 cases, 6 of which were fatal, the vascular injury was the only complicating wound.

In the 1,155 cases in which adequate data on the multiplicity factor were available for the tabulation (table 58), there was a definite and almost arithmetical increase in the case fatality rate from 19.5 percent in univisceral injuries (22.7 percent in wounds of the colon, 14.1 percent in wounds of the rectum) to 100 percent when 5 additional organs were injured. The outcome in every injury of the colon apparently depended more upon the number of additional organs injured than upon precisely which organs were involved.

It should be noted that while the case fatality rate rose progressively for each additional organ injured, there was no consistent increase in the rate for the various time intervals after injury. The timelag, naturally, is not unimportant. In view of the danger of infection of the peritoneum in wounds of the large bowel, timelag was probably more important in such wounds than in any other type of abdominal wound. When the figures are interpreted in the light of these various considerations, they strongly suggest that reduction of the timelag in patients with wounds of the large bowel enhanced their chances of survival. On the other hand, the bad effects of delay in surgery, the chief of which was the development of peritonitis, were overshadowed by the increased influence of multiple visceral injury, the chief of which was probably shock.

SHOCK

On the basis of clinical appearance, blood pressure, amounts of blood and plasma used in resuscitation, response to measures of resuscitation, and similar criteria, it was possible to classify 1,140 patients according to the degree of shock present when they were admitted to the field hospital (table 59). Approximately a third of this number was in each of the three categories; namely, no shock or slight shock, moderate shock, and severe shock. The case fatality rate increased proportionately with the increase in the degree of shock, though when the cases were classified according to the timelag no pronounced differences were observed (table 59) except in the 12- to 18-hour period. On the other hand, it seems reasonable to surmise that, as time passed without treatment, patients who at first were in minor degrees of shock entered more serious states and so fell into different categories. The degree of shock, as would have been expected, was also related to the number of organs injured.

Resuscitation therapy.—In the immediate resuscitation and preparation for operation of patients with wounds of the colon, the greatest reliance was placed upon blood, which was used immediately, liberally, and always in larger amounts than plasma (table 60). The quantities of plasma, however,

were probably larger than the tabulated data suggest, because under field conditions the full amounts used were not always recorded.

TABLE 59.—*Influence of degree of shock and timelag on case fatality rates in 1,140 injuries of colon and rectum*¹

Timelag	Degree of shock									Total		
	None to slight			Moderate			Severe					
	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate
0 to 6 hours.....	217	24	11.1	199	58	29.1	225	153	68.0	641	235	36.7
6 to 12 hours.....	101	7	7.0	103	24	23.3	125	84	67.2	329	115	35.0
12 to 18 hours....	24	1	4.2	32	15	47.0	24	20	83.3	80	36	45.0
18 to 24 hours....	20	3	15.0	11	1	9.1	12	9	75.0	43	13	30.2
Over 24 hours....	21	3	14.3	14	7	50.0	12	8	66.7	47	18	38.3
Total.....	353	38	9.9	359	105	29.2	398	274	68.8	1,140	417	36.6

¹ Data on these points are lacking in 82 cases.

TABLE 60.—*Blood and plasma replacement in wounds of colon and rectum*¹

Cases	Units ²	Average per patient
Blood:		cc.
Total.....	4,165	1,841
Survivals.....	2,043	1,415
Deaths.....	2,122	2,590
Plasma:		
Total.....	3,220	728
Survivals.....	1,722	610
Deaths.....	1,498	938

¹ The figures for blood are based on 1,131 casualties and for plasma on 1,106 casualties.

² A unit of blood is 500 cc. and a unit of plasma is 250 cc.

It was the policy in the earlier cases in this series to delay operation until the systolic blood pressure was over 100 mm. Hg. As experience increased, this policy was replaced by a regimen in which operation was performed earlier in the period of resuscitation and active shock therapy was continued throughout the operative procedure. The timelag before operation was thus shortened in numerous cases in which full resuscitation before operation was notably hard to achieve, particularly in severe injuries of the right colon, evisceration, and active abdominal hemorrhage. Casualties with wounds of the colon associated with extensive fecal soiling showed marked resistance to resuscitation therapy.

TREATMENT

While on first glance (table 61) it might seem that a very large number of procedures were utilized in the 1,222 wounds of the colon and rectum which make up this series, actually there was no wide divergence of opinion among surgeons in the 2d Auxiliary Surgical Group over how wounds of the large bowel should be managed. There were numerous modifications of technique, it is true, but the opinion of the various teams was probably as definite, as concrete, and as unanimous concerning methods of management as it was in any intra-abdominal injury. Exteriorization of the injured bowel was a fundamental principle, though several different techniques were employed to accomplish it, and procedures other than exteriorization were resorted to only when for any reason it was inadvisable or actually impossible to perform this operation.

In general, all surgical procedures for wounds of the colon and rectum involved three basic techniques:

1. Exteriorization of the wounded segment of bowel, to prevent intraperitoneal leakage at a suture line. The damaged exteriorized segment could be used as the site of colostomy on appropriate indications.

TABLE 61.—*Influence of location of injury and type of operation on case fatality rates in 1,222 wounds of colon and rectum*

Operation	Ascending colon	Transverse colon	Descending colon	Ascending and transverse colon	Descending and transverse colon	Ascending and descending colon	Sigmoid	Extraperitoneal rectum	Colon and extraperitoneal rectum	Total
Colostomy:										
Loop.....	145	252	67	3	8	2	82			559
Spur.....	27	146	48	9	29	1	32			292
Tube.....	39	4								43
Intraperitoneal closure, proximal colostomy.....	1	1	3	6	9	6	34			60
Diversional colostomy.....								8	2	10
Resection, ileocolic anastomosis, and colostomy.....	29			6						35
Resection, double-barreled ileocolostomy.....	17	2		6					1	26
Posterior drainage, proximal colostomy.....								82	19	101
Posterior drainage, closure, proximal colostomy.....							4	25	17	46
Closure only.....	13	6	1	2				1		23
Resection, separate exteriorization of limbs.....	2	3			2		2			9
No intestinal operation ¹	9	3	1	1	1		3			18
Total cases.....	282	417	120	33	49	9	157	116	39	1,222
Total deaths.....	87	161	42	19	19	6	52	27	20	433
Case fatality rates.....	30.9	38.6	35.0	57.6	38.8	66.7	33.1	23.3	51.3	35.4

¹ In 5 of these 18 injuries (3 involving the ascending, 1 the transverse, and 1 the descending colon) the wound was over-looked at laparotomy. Eleven of the remaining patients died on the operating table before the intestinal lesion was dealt with. The other two developed, respectively, a pelvic abscess and a fecal fistula and underwent secondary surgery for these complications.

2. Diversion of the fecal stream away from wounds of the distal or lower colon and rectum, which was accomplished by any one of several techniques of colostomy. Colostomy was always performed for perforation of the rectum, but adequate posterior drainage through the fascia propria was also mandatory.

3. Incomplete diversion of the fecal stream, which was a temporary measure, designed for purposes of decompression as well as to bring the bowel to the surface, so that a diversional colostomy could be performed. Either a tube or a tangential enterostomy was utilized in the cecum, though this type of opening could not be converted into a diversional colostomy.

Special procedures carried out in these wounds of the colon and rectum were as follows:

1. Loop colostomy, which was a simple exteriorization of a segment of colon through an abdominal incision. The exteriorized segment was maintained by a tube laid across the incision and under the segment of colon (fig. 28A).

2. Spur colostomy, which was exteriorization of a segment of colon or of the proximal and distal ends of a segment of colon, through an abdominal incision. Both limbs of the colostomy were sutured together along the anti-mesenteric surface for a distance of 3 to 4 inches to form the spur (fig. 28B). The colon was rotated so that the mesentery lay medially.

3. Tube cecostomy, which was an enterostomy with a rubber tube sutured into the lumen of the colon and brought out through a small abdominal incision (fig. 28C).

4. Intraperitoneal closure with proximal colostomy, which consisted of repair of the perforated colon which was left in the peritoneal cavity while a loop or spur colostomy was done at a convenient distance proximal to the repair.

5. Diversional colostomy, which was a spur or loop colostomy placed proximal to a perforation of the colon or rectum to divert the fecal stream.

6. Resection with ileocolic anastomosis and colostomy. This was a procedure (fig. 29A) which included (1) resection of the terminal ileum and ascending colon; (2) closure of the terminal end of the ileum; (3) side-to-side anastomosis of the ileum and transverse colon, the anastomosis being left in the peritoneal cavity; and (4) exteriorization of the proximal end of the transverse colon as a mucous fistula through a separate incision in the abdominal wall. This procedure was sometimes varied by performing end-to-side ileocolostomy with exteriorization of the proximal end of the colon (fig. 29B). Another variation of the basic technique was the performance of a side-to-side anastomosis between the ileum and transverse colon, with exteriorization of the distal end of the ileum and the proximal end of the transverse colon through separate incisions in the abdominal wall, to create mucous fistulas (fig. 29C).

7. Resection with double-barreled ileocolostomy, which was essentially the same as resection with spur colostomy, the only difference being that one of the exteriorized limbs was ileum and one was colon (fig. 30A).

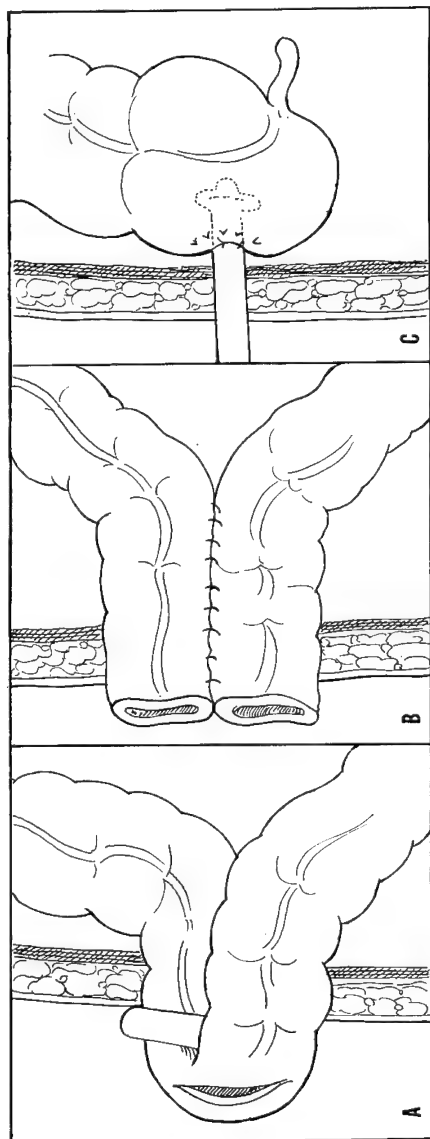


FIGURE 28.—Types of colostomy. A. Loop colostomy. B. Spur colostomy. C. Tube colostomy.

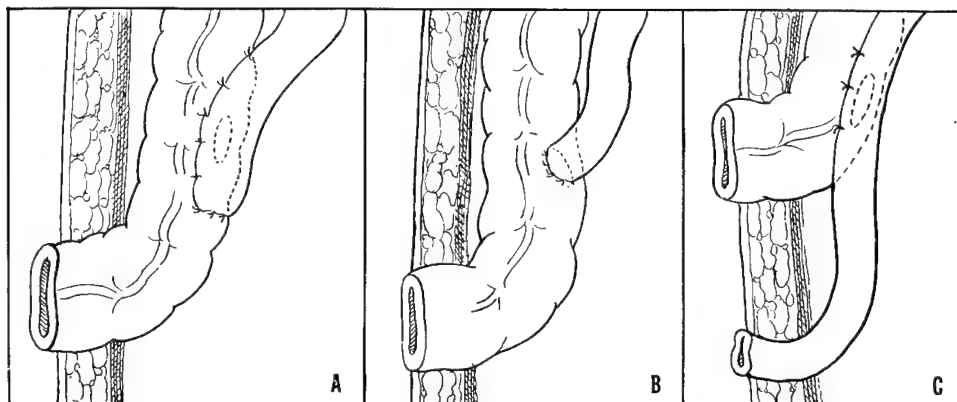


FIGURE 29.—Types of colostomy. A. Resection of wounded segment, with side-to-side ileocolic anastomosis and creation of single mucous fistula. B. Same, with end-to-side anastomosis. C. Same with side-to-side anastomosis and creation of double mucous fistulas.

8. Posterior drainage (drainage of the fascia propria) and proximal colostomy, which was indicated in wounds of the rectum or of the rectum and the sigmoid. It included (1) a coccygectomy or an incision just lateral to the coccyx; (2) freeing of the rectum from the fascia propria for drainage of the perforated rectum, which was not repaired; and (3) creation of a proximal loop or spur colostomy through an abdominal incision. One variation of this technique was to repair the perforated rectum and drain the perirectal space.

9. Resection, with separate exteriorization of the limbs, which required resection of a segment of the colon with exteriorization of the proximal and distal limbs through individual abdominal incisions rather than as a double-barreled colostomy.

10. Tangential colostomy, which was exteriorization of a small area of the antimesenteric wall of the colon through a separate abdominal incision (fig. 30B), with maintenance of the continuity of the bowel.

Whenever the retroperitoneal space had been penetrated or perforated, it was drained through an independent incision. The peritoneal cavity itself was drained in not more than 10 percent of the remaining cases.

REGIONAL INJURIES

The transverse colon alone was involved in the largest number of cases in this series (417 cases, 34.2 percent), followed in the descending order of frequency by the ascending colon (282 cases, 23.1 percent), sigmoid (157 cases, 12.8 percent), descending colon (120 cases, 9.8 percent), extraperitoneal rectum (116 cases, 9.5 percent), transverse and descending colon (49 cases, 4.0 percent), colon and rectum (39 cases, 3.2 percent), ascending and transverse

colon (33 cases, 2.7 percent), and ascending and descending colon (9 cases, 0.7 percent).

The appendix was either perforated or transected in 12 instances (1.0 percent of the total number of wounds of the large bowel). All of these patients had other and more important intra-abdominal wounds. All were treated by appendectomy.

Ascending colon.—Wounds of the ascending colon (table 62) presented particularly difficult problems when it was necessary to resect the entire right colon and terminal ileum. Early in the war, the most favored procedure under these circumstances was resection and double-barreled ileocolostomy, but it carried a case fatality rate of almost 65 percent and was unsatisfactory for other reasons. It combined the most undesirable feature of small-bowel fistula, that is, an irritant and digestive discharge, with the contaminating discharge of a colostomy. The resulting fecal contamination of irritated and digested wound surfaces produced conditions which at times it was impossible to control. Later, resection and ileocolic anastomosis and colostomy, with the creation of a single or double mucous fistula, accomplished some improvement in the case fatality rate, which still, however, remained high (51.7 percent). Two patients who required resection of a portion of the ascending colon were treated by separate exteriorization of the proximal and distal ends; both died.

There were no deaths in the 27 patients treated by tangential colostomy (included under loop colostomy, table 62). This method was employed only when the perforation was small and was located on the antimesenteric border of the bowel. Two techniques were used: The bowel was repaired and no fecal fistula was established at operation, or it was not repaired and the perforation was permitted to serve as the fistula.

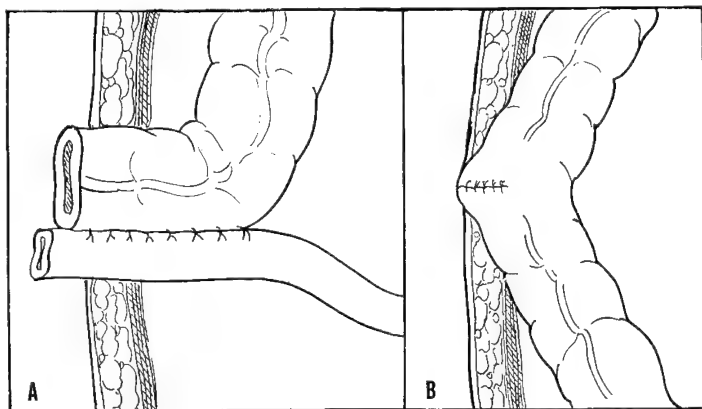


FIGURE 30.—Types of colostomy. A. Double-barreled ileocolostomy.
B. Tangential colostomy.

TABLE 62.—*Influence of technique on case fatality rates in 273 wounds of ascending colon*¹

Operation	Cases	Deaths	Case fatality rate
Colostomy:			
Loop.....	145	32	22.1
Spur.....	27	10	37.0
Tube.....	39	10	25.6
Closure, proximal colostomy.....	1	0	0
Resection, ileocolic anastomosis and colostomy.....	29	15	51.7
Resection, double-barreled ileocolostomy.....	17	11	64.7
Closure only.....	13	1	7.7
Resection, separate exteriorization of limbs.....	2	2	100.0
Total.....	273	81	30.0

¹ Nine additional cases are omitted because no intestinal operation was performed in them: Six patients died on the operating table, and in 3 cases, 2 of which were fatal, the lesion was missed.

Thirteen patients with injuries of the right side of the colon were subjected to primary repair, without colostomy, with only one death. The results are not statistically significant, nor are they of particular significance clinically. These patients were among the least seriously wounded and are in no wise comparable to the casualties who required resection of the right side of the colon. They are not even comparable to casualties with large single wounds of the colon.

Transverse colon.—The 417 wounds of the transverse colon included 6 comparatively minor injuries in which primary repair of the perforation was successfully carried out without colostomy (table 63). All these six patients made smooth recoveries. No special comment is necessary on any of the other cases in this group.

TABLE 63.—*Influence of technique on case fatality rates in 414 wounds of transverse colon*¹

Operation	Cases	Deaths	Case fatality rate
Colostomy:			
Loop.....	252	80	31.7
Spur.....	146	72	49.3
Tube.....	4	2	50.0
Closure, proximal colostomy.....	1	0	0
Resection, double-barreled ileocolostomy.....	2	1	50.0
Closure only.....	6	0	0
Resection, separate exteriorization of limbs.....	3	3	100.0
Total.....	414	158	38.2

¹ Three additional cases are omitted because no intestinal operation was performed in them. Two patients died on the operating table, and in 1 case, also fatal, the lesion was missed.

Descending colon.—Wounds of the descending colon (table 64) presented no special problems as compared with wounds of the ascending colon or the lower sigmoid. All were dealt with by some form of colostomy except for the single case managed by repair of the perforation with return of the bowel to the peritoneal cavity.

Sigmoid colon.—Wounds of the sigmoid colon (table 65) presented two problems not encountered in wounds of the colon proximal to the sigmoid:

1. When a perforation of the lower sigmoid was present, it was often impossible to exteriorize the wounded segment because the distal bowel was not long enough. In this type of case, the perforation was repaired and a proximal diversion colostomy of either the loop or the spur type was created.

TABLE 64.—*Influence of technique on case fatality rates in 119 wounds of descending colon*¹

Operation	Cases	Deaths	Case fatality rate
Colostomy:			
Loop-----	67	19	28.4
Spur-----	48	21	43.8
Closure, proximal colostomy-----	3	1	33.3
Closure only-----	1	0	0
Total-----	119	41	34.5

¹ An additional (fatal) case is omitted because the lesion was missed at operation.

TABLE 65.—*Influence of technique on case fatality rates in 154 wounds of sigmoid colon*¹

Operation	Cases	Deaths	Case fatality rate
Colostomy:			
Loop-----	82	21	25.6
Spur-----	32	14	43.8
Closure, proximal colostomy-----	34	11	32.4
Posterior drainage, closure, proximal colostomy-----	4	1	25.0
Resection, separate exteriorization of limbs-----	2	2	100.0
Total-----	154	49	31.8

¹ Three additional cases are omitted because the patients died on the operating table before the intestinal operation could be performed.

2. The second problem, which was encountered in only four cases, concerned perforations at the rectosigmoid junction, just at the reflection of the peritoneum on the pelvic floor. In these cases, the procedure just described

was followed, with the addition of fascia propria (posterior) drainage of the rectum.

Rectum.—The majority of patients with injuries of the extraperitoneal rectum (table 66) were treated by proximal colostomy and posterior drainage. The perforation was closed in 25 of the 107 cases in which this technique was used.

Multiple intestinal injuries.—The case fatality rate, as might have been expected, increased sharply when more than one segment of the large bowel had been wounded (tables 67 to 70, inclusive). Of the 1,222 patients in this series, 130 had injuries of two different segments of the colon or injuries of the colon and rectum. There were 64 deaths in this group (49.2 percent). There were 17 deaths (39.5 percent) in the 43 cases in which colostomies were created at two different sites.

TABLE 66.—*Influence of technique on case fatality rates in 116 wounds of extraperitoneal rectum*

Operation	Cases	Deaths	Case fatality rate
Diversional colostomy.....	8	5	62.5
Posterior drainage, proximal colostomy.....	82	15	18.3
Posterior drainage, closure, proximal colostomy.....	25	6	24.0
Closure only.....	1	1	100.0
Total.....	116	27	23.3

TABLE 67.—*Influence of technique on case fatality rates in 32 wounds of ascending and transverse colon*¹

Operation	Cases	Deaths	Case fatality rate
Colostomy:			
Loop.....	3	0	0
Spur.....	9	6	66.7
Closure distal perforation, loop exteriorization proximal perforation.....	6	3	50.0
Resection, ileocolic anastomosis and colostomy.....	6	4	66.7
Resection, double-barreled ileocolostomy.....	6	4	66.7
Closure only.....	2	1	50.0
Total.....	32	18	56.3

¹ An additional case is omitted because the patient died on the operating table before the intestinal operation could be completed

TABLE 68.—*Influence of technique on case fatality rates in 9 wounds of ascending and descending colon*

Operation	Cases	Deaths	Case fatality rate
Colostomy:			
Double loop.....	1	1	100.0
Spur and loop.....	1	1	100.0
Tube and loop.....	1	0	0
Closure distal perforation, loop exteriorization proximal perforation.....	6	4	66.7
Total.....	9	6	66.7

TABLE 69.—*Influence of technique on case fatality rates in 48 wounds of transverse and descending colon*¹

Operation	Cases	Deaths	Case fatality rate
Colostomy:			
Double loop.....	9	3	33.3
Spur and loop.....	29	11	38.0
Proximal tube, distal loop.....	1	0	0
Closure distal perforation, exteriorization proximal perforation.....	9	4	44.4
Total.....	48	18	37.5

¹ An additional case is omitted because the patient died on the operating table before the intestinal operation could be completed.

TABLE 70.—*Influence of technique on case fatality rates in 39 combined wounds of colon and rectum*

Operation	Cases	Deaths	Case fatality rate
Diversional colostomy.....	2	1	50.0
Resection, double-barreled ileocolostomy, loop sigmoidostomy.....	1	1	100.0
Posterior drainage, proximal colostomy.....	19	9	47.4
Posterior drainage, closure, proximal colostomy.....	17	9	52.9
Total.....	39	20	51.3

Up to May 1944, when penicillin first became available, sulfadiazine was given by vein after operation in all injuries of the colon and rectum. Thereafter, penicillin was given at 3-hour intervals from the time the patient reached the hospital until 5 days, or more, after operation. A few surgeons continued to use sulfadiazine intravenously in conjunction with it.

Some surgeons who used no antibacterial agent in the abdomen in mildly contaminated cases are known to have employed this method when contamination of the peritoneal cavity was serious or massive. The case fatality rate in wounds of the colon and rectum does not seem to have been materially affected by the introduction of either chemotherapeutic or antibiotic agents into the peritoneal cavity.

POSTOPERATIVE COMPLICATIONS

According to the records, important postoperative complications included peritonitis, pneumonia, anuria, wound infection, atelectasis, evisceration, intestinal obstruction, anaerobic infection, fecal fistula, empyema, secondary hemorrhage, subphrenic abscess and pelvic abscess, pulmonary edema, cerebral embolism, and fat embolism. The list is necessarily presented without comment, since the records were entirely inadequate. Unquestionably, there were more instances of nonfatal atelectasis and patchy bronchopneumonia than the records indicate, just as there were unquestionably many more wound infections, minor hemorrhages, and temporary partial obstructions from edema in the area of intestinal anastomoses. As for minor complications, the majority were simply not entered on the charts.

CASE FATALITY RATES

There were 433 deaths in forward hospitals among the 1,222 patients with perforations of, or other severe damage to, the colon, rectum, or both, a case fatality rate of 35.4 percent (table 55, p. 255). Actually, for reasons pointed out elsewhere (p. 85), there is little doubt that the rate was somewhat higher than these figures indicate.

The case fatality rates for injuries of the large bowel improved progressively as the war progressed. In 1943, there were 58 deaths in 136 casualties (42.6 percent); in 1944, 334 deaths in 917 casualties (36.4 percent); and in 1945, 99 deaths in 305 casualties (32.5 percent).

Case fatality rates varied according to the location of the injury (table 71) and according to whether the wound was limited to the large bowel or was multivisceral. In univisceral injuries of the colon, the rate was 22.7 percent (table 55, p. 255). In univisceral injuries of the extraperitoneal rectum, it was 14.1 percent. In multivisceral injuries, these rates were, respectively, 40.3 and 34.6 percent. When the wounds involved both the colon and the rectum, the rate for univisceral injuries was 46.2 percent and for multivisceral injuries 53.8 percent.

When only univisceral injuries of the large bowel were considered (table 71), the case fatality rate was found to vary according to the site of the wound and the number of wounds. Casualties who had sustained injuries of the extra-peritoneal rectum had the best chance of survival, the rate for these wounds being 14.1 percent. Those with combined injuries of the colon and rectum had the least chance, the rate for these wounds being 46.2 percent. Univisceral wounds of the colon carried a higher case fatality rate (22.7 percent) than similar wounds of any other organ except the stomach (table 36, p. 218).

TABLE 71.—*Influence of site of injury on case fatality rates in 328 univisceral wounds of colon and rectum*

Site of injury	Cases	Deaths	Case fatality rate
Right colon.....	107	20	18.7
Transverse colon.....	60	14	23.3
Left colon.....	65	17	26.2
Multiple injuries of colon.....	19	6	31.6
Rectum.....	64	9	14.1
Colon and rectum.....	13	6	46.2
Total.....	328	72	22.0

CAUSES OF DEATH

It is not possible to state the causes of death with complete accuracy in the 433 patients who died with injuries of the colon and rectum (table 72). In many instances, injuries of other viscera, as well as associated injuries of the head, extremities, and chest, were probably responsible, wholly or in part, for the fatality. In 36 cases, the cause of death was not stated at all on the records, and it was not possible to determine it from the data available. Most of the remaining 397 patients were subjected to partial or complete necropsy, or the records were sufficiently detailed and specific to permit a primary cause of death to be determined.

Shock.—Shock, which occurred in 185 cases, 46.6 percent of the fatalities in which the cause of death could be determined, was the largest single primary cause of death. The patients in this group were all gravely wounded. On admission to the field hospital, they were almost invariably in severe shock, which usually did not respond fully, if at all, to adequate preoperative resuscitative therapy. All were operated on, but they usually did not respond to heroic measures employed during and after operation. Sometimes they did not react at all after surgery. Thirteen died on the operating table. A few lived as long as 36 hours, but in most of the fatal cases those who survived the operation died within 24 hours. In numerous instances, it was not possible to determine

TABLE 72.—*Distribution of primary causes of death in 397 injuries of colon and rectum*¹

Cause	Cases	Proportion
		Percent
Shock.....	185	46.6
Intra-abdominal:		
Peritonitis, generalized.....	87	21.8
Hemorrhage.....	6	1.5
Cellulitis (retroperitoneal).....	5	1.3
Abscess.....	5	1.3
Anaerobic infection.....	5	1.3
Intestinal obstruction.....	4	1.0
Total.....	112	28.2
Anuria.....	² 35	8.8
Intrathoracic:		
Pneumonia.....	13	3.3
Pulmonary embolus.....	11	2.8
Pulmonary edema.....	7	1.7
Severe chest injury.....	6	1.5
Atelectasis.....	4	1.0
Blast injury.....	4	1.0
Total.....	45	11.3
Cranial:		
Head injury.....	6	1.5
Fat embolism.....	1	.25
Total.....	7	1.8
Other:		
Anaerobic infection.....	4	1.0
Injury of extremity.....	1	.25
Not recorded, but primary cause clearly not intra-abdominal.....	8	2.0
Total.....	13	3.3
Total deaths from known causes.....	397	100.0

¹ Exclusive of 36 cases in which the primary cause of death was not stated.² In some of these cases hemorrhage, shock, and peritonitis perhaps played the dominant role.

whether death was caused by shock alone or by a combination of shock and the effects of an overwhelming peritoneal contamination. There is no doubt that it occurred before a fatal type of infectious peritonitis was established, but there is also no doubt that in most of these early fatal cases there was enough irritative peritoneal contamination, from the spill of feces, small-bowel contents, and bile,

blood, and urine, to cause a shock reaction. The actual loss of blood, in combination with other factors, was of enormous importance in these patients in the causation of the severe and fatal type of shock which they presented.

Death from shock was particularly likely to occur after operation for extensive wounds involving the right side of the colon, the cecum, and the lower ileum, the reason being that in these portions of the bowel the contents are liquid and possess notably irritating properties. The high case fatality rates in these injuries were disturbing, and there were frequent changes in the plan of management, with, however, no great improvement in results.

Intra-abdominal causes of death.—Intra-abdominal causes of death were responsible for the fatalities in 112 cases, 28.2 percent of the total number (table 72). All these deaths were the direct or indirect result of infection except for six in which hemorrhage was the primary cause. Postoperative hemorrhage was, however, unimportant in this series as a primary cause of death.

In 87 cases (21.8 percent of the total number of deaths), the peritonitis present was sufficiently extensive to assign to it the primary role in the fatality. Fatal peritonitis was most frequent in lesions of the right side of the colon, in which it accounted for 24 percent of the fatalities, and least frequent in sigmoid lesions, in which it was responsible for 15 percent. Peritonitis was less to be feared in World War II than in former wars, and it is difficult to see how the number of deaths from this cause could have been further reduced. There was no evidence that the intraperitoneal use of chemotherapeutic and antibiotic agents greatly influenced the case fatality rates, though there is no doubt that the systemic use of sulfonamide drugs, replaced or supplemented by penicillin after the latter became generally available in May 1944, had an important role in the control and treatment of peritoneal infections.

A number of patients probably died of peritonitis who might have survived the infection if it had not been present in association with another serious lesion. Others who died from peritonitis during periods of great tactical activity would perhaps have been saved if they could have had the individualized treatment which this condition demands but which was practical only when fighting was less intense.

Two of the five deaths from retroperitoneal cellulitis occurred in patients with wounds of the extraperitoneal portion of the rectum. In the three other cases in this group, the original lesions were distributed over the colon, from the ascending portion to the sigmoid. Of the 5 deaths from intraperitoneal abscess, 1 followed a wound of the ascending colon and 4 followed wounds of the transverse colon. Figures relative to abscess formation must not be accepted absolutely, since this complication was a delayed development and deaths caused by it usually occurred in second or third echelon hospitals.

All five deaths from intraperitoneal anaerobic infections occurred prior to February 1944. Whether the availability of penicillin soon after this date played any part in the improvement, it is not possible to say.

All four patients who died of intestinal obstruction also had injuries of the small bowel, which in every instance was the site of the obstruction. In two

known instances, the obstruction followed the breakdown of an intestinal anastomosis. The number of deaths from intestinal obstruction must be evaluated in the light of the fact that this complication, like abscess formation, was often a late development, and fatalities caused by it were as likely to occur in rear as in forward hospital installations.

Intrathoracic causes of death.—The 45 deaths from intrathoracic causes accounted for 11.3 percent of the total number. The majority need no particular comment. The fact that pneumonia was responsible for only 13 deaths can probably be attributed to two circumstances: (1) The routine use of chemotherapeutic and antibiotic agents, and (2) the skill of the anesthetists who worked with the surgeons on these cases. Endotracheal anesthesia and tracheobronchial aspiration during and after operation must be assigned an important role in the prevention and control of postoperative atelectasis and, in turn, in the prevention of the pneumonic process which so frequently follows this complication.

Other causes of death.—The remainder of the deaths following wounds of the colon and rectum (table 72) were attributable to a variety of causes and for the most part need no special comment. In 2 of the 4 fatal anaerobic infections, the infection was in a wound of the extremity. The infection in the two other cases was considered autogenous; it was apparently the result of direct contamination of the wounds of the buttocks and flank from the wound of the large bowel.

CHAPTER XXI

Wounds of the Liver and of the Extrahepatic Biliary Tract (829 Casualties)

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The 829 wounds of the liver which are discussed in this chapter occurred in 3,066 ¹ of the 3,154 abdominal injuries observed by the 2d Auxiliary Surgical Group during 1944 and 1945 (table 73). Four hundred and forty-six (53.8 percent) were thoracoabdominal. The case fatality rate in this group was 24.0 percent (107), against 27.0 percent (224) for the whole group. In 51 of the 829 wounds of the liver, the gallbladder was injured, and the extrahepatic biliary ducts were injured in 2 others. There were 16 deaths in these 53 cases.

TABLE 73.—*Essential data in 829 wounds of liver*

Type of wound	Cases	Frequency		Deaths	Case fatality rate
		In 3,066 abdominal injuries	In 829 liver injuries		
		Percent	Percent		
Univisceral.....	339	11. 1	40. 9	33	9. 7
Multivisceral.....	490	16. 0	59. 1	191	39. 0
Total.....	829	27. 0	100. 0	224	27. 0

NATURE OF INJURY

The majority of these injuries occurred in the right lobe of the liver, as might have been expected because of its greater size. In the 538 cases observed in 1944 in which these data were accurately stated, the right lobe was involved 446 times (82.9 percent), the left lobe 73 times, and both lobes 19 times. In-

¹ Calculations for injuries of the liver are made on a total of 3,066 abdominal injuries, instead of on 3,154, the base figure for all other calculations. When the 88 histories which represent the difference between the two totals became available, the medical officers who had done the work on wounds of the liver had been transferred from the command, and it was thought wiser not to change their tabulations.

involvement of adjacent viscera could usually be explained by the location of the hepatic injury. Wounds about the hilum were seldom seen, possibly because its protected location kept it from injury but more probably because most such injuries were immediately fatal. Injuries in this area involved such structures as the extrahepatic biliary ducts, the retroperitoneal portion of the duodenum, the pancreas, the stomach, the colon, and the vena cava.

Most wounds of the liver were lacerating, penetrating, or perforating. Penetrating wounds were usually less serious than those which involved larger masses of tissue, though they were sometimes followed by graver complications, such as bile leakage or hemorrhage. Twenty-four percent of all hepatic injuries were severe, sometimes severe enough to require resection of a part of a lobe. The remaining wounds were described as of slight or moderate severity.

Bleeding from the liver, which was only occasionally described as severe, had ceased at the time of exploration in 91.1 percent of all cases. The significance of this observation will be discussed later (p. 278).

Some bile leakage had occurred in practically every case, but the presence of blood and exudate in the peritoneal cavity, and sometimes of intestinal content also, made an estimate of the amount of bile spill impossible.

EVOLUTION OF METHODS OF MANAGEMENT

The management of wounds of the liver by surgeons of the 2d Auxiliary Surgical Group was a matter of evolution and the result of their own clinical observations. They had no decisive principles of therapy to guide them. Observations of military surgeons in World War I were brief and frequently contradictory. Bailey² advocated expectant treatment if it were possible to be certain that the wound affected only the liver. Lee³ and Wallace⁴ also favored nonintervention in most cases. The Committee on Surgery of the National Research Council⁵ apparently felt that, in World War II, operative therapy would be necessary more often than it had been in the past.

All of these observers recognized the possibility that spontaneous hemostasis might occur in injuries of the liver, but they placed different degrees of reliance upon it. Bailey felt that physiologic changes incidental to anesthesia and surgery might cause renewed bleeding. On the contrary, Wallace's⁶ experience that spontaneous hemostasis usually occurred within 6 to 10 hours of wounding is in close agreement with the experience of the 2d Auxiliary Surgical Group.

The observers cited were in general agreement about the possibility of secondary hemorrhage from the liver, although there was some variance of

² Bailey, Hamilton: *Surgery of Modern Warfare*. Edinburgh: E. & S. Livingstone, 1941-42.

³ The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1.

⁴ Wallace, Cuthbert: *War Surgery of the Abdomen*. London: J. & A. Churchill, 1918.

⁵ Abdominal and Genito-Urinary Injuries. *Military Surgical Manuals*. Prepared under the auspices of the Committee on Surgery of the Division of Medical Sciences of the National Research Council. Philadelphia and London: W. B. Saunders Co., 1942.

⁶ See footnote 4.

opinion about its frequency and danger. Makins⁷ stated that secondary hemorrhage did not occur in the absence of sepsis.

Lee⁸ advised suture of the liver in preference to packing. Wallace⁹ gave diametrically opposite advice. Bailey,¹⁰ while admitting the theoretic superiority of suture, nevertheless concluded that packing was "infinitely better" because of the technical difficulties attending suture of the liver. Packing, suture, and free muscle grafts were all mentioned by the Committee on Surgery of the National Research Council as permissible methods for the accomplishment of hemostasis and repair of hepatic wounds.¹¹ Comments on the use of simple drainage and on the risk of bile peritonitis were notably lacking in these discussions of hepatic injuries.

The greatest measure of agreement among surgeons prior to World War II was their advocacy of expectant or conservative treatment, or no treatment at all, for most wounds of the liver. Many of these men were surgeons who had carried over the idea from their experience in World War I. This policy, however, was incompatible with the surgical philosophy of World War II, in which operative intervention was held to be in the best interests of practically every casualty with an abdominal wound if he lived to reach a forward hospital. Since the liver was frequently wounded, both alone and in combination with other organs, the problem of management of hepatic injuries became important early in the war.

During the initial activities of the 2d Auxiliary Surgical Group in 1942-43 (a period not covered by these data), wounds of the liver were variously managed by packing, suture, free muscle grafts, and expectant treatment. Suture and muscle grafts proved impractical in the hands of most surgeons, and expectant treatment was not thought to be reliable. During this period, therefore, gauze packing was the most frequently used of all methods. As time passed, however, serious complications were observed following this technique. The removal of gauze packs in field hospitals was more than once attended by disastrous hemorrhage. Abscesses occurred within the liver or the perihepatic space, and necrosis of hepatic tissue occurred in areas which had been packed. Hepatitis and biliary peritonitis were other complications. These and other undesirable results of gauze packs were emphasized in Burford's¹² report of hepatic injuries observed in a general hospital.

Early removal of the pack was practiced in some cases in an attempt to prevent these complications, but this plan was not successful. As soon as the pack was removed, the external wound tended to close prematurely. Attempts to substitute Penrose drains for packs were also unsuccessful. Adequate

⁷ Makins. Cited by Bailey. See footnote 2, p. 276.

⁸ See footnote 3, p. 276.

⁹ See footnote 4, p. 276.

¹⁰ See footnote 2, p. 276.

¹¹ See footnote 5, p. 276.

¹² Review of 1,000 Thoracic Cases. Bull. U. S. Army. M. Dept. 89: 70-72, June 1945.

drainage by this means proved impossible except under direct vision, when the abdomen was open.

By early 1944, many surgeons of the group had concluded that the use of packs in wounds of the liver was associated with too many risks to justify their employment if it could possibly be avoided. They had become aware of the frequency with which spontaneous hemostasis was observed in fresh wounds, and it seemed to them that the only justification for the use of a pack was the prevention of secondary hemorrhage. Since this was not a frequent complication, a trend began away from the use of gauze packs and toward simple drainage of the subhepatic space (Morison's pouch). At first there was some disagreement concerning the necessity for drainage, but the presence of bile in discharges in a substantial proportion of cases when both drains and gauze packs were used, as well as the frequent observation of bile in the peritoneal cavity in wounds of the liver, convinced most surgeons of the necessity for external drainage as a protection against bile peritonitis.

Some surgeons continued to close the abdomen without drainage when the injuries of the liver were limited to lacerations or penetrations which required no special treatment. The majority, however, took the position that all injuries required drainage, on the ground that it was impossible to predict, in a given case, whether bile leakage would or would not occur. In a few patients with thoracoabdominal wounds, troublesome bile empyema resulted from failure to drain the subphrenic space after operation had been performed through the right thorax. It was the consensus that this complication would probably not have occurred in these cases if drainage had been instituted through a subcostal incision.

These clinical observations led to almost complete abandonment of packing as a method of treatment in hepatic injuries and to its almost universal replacement by drainage of Morison's pouch. The data recorded in this chapter substantiate the soundness of this change of policy. The almost total absence of postoperative hemorrhage in the cases which were drained indicates that this risk had been overemphasized early in the war. Similarly, the efficacy of drainage as a means of preventing bile peritonitis is attested by the absence of this complication in the cases treated by this method.

TREATMENT

The location of the incision in injuries of the liver (table 74) naturally depended, in any given case, upon the extent of the injury or injuries, and, in particular, upon whether the wound was abdominal or thoracoabdominal. The popularity of the transdiaphragmatic approach increased as the war progressed. In an occasional case, thoracolaparotomy was employed; the incision was extended over the chest wall onto the abdomen, the costal arch being cut or the incision passing through the 10th or 11th intercostal space.

In many wounds of the liver, there was sufficient fragmentation of the organ to necessitate actual resection of the damaged tissue instead of debride-

ment. Often a substantial amount of tissue had to be removed. In this sort of case, it was not unusual to find completely detached pieces of liver lying free in the peritoneal cavity as a result of the original trauma.

TABLE 74.—*Distribution of surgical approaches in 432 wounds of liver*

Approach	1944		1945		Total	
	Cases	Proportion	Cases	Proportion	Cases	Proportion
Laparotomy.....	172	Percent 53.0	42	Percent 39.3	214	Percent 49.6
Thoracotomy.....	107	32.9	50	46.7	157	36.3
Combined laparotomy and thoracotomy.....	40	12.3	14	13.1	54	12.5
Thoracolaparotomy ¹	6	1.8	1	.9	7	1.6
Total.....	325	100.0	107	100.0	432	100.0

¹ In this technique, the thoracic incision was extended across the costal arch onto the abdominal wall.

In a sample of 695 cases observed in 1944 and 1945 in which full data concerning treatment were available (table 75), the changing proportions of cases treated by drainage and by packing are a significant reflection of increasing surgical experience. Though originally some wounds of the liver were regarded as too small to require drainage, this attitude became less and less frequent as the war progressed. In some cases in which drainage was instituted, there was no bile in the discharge after operation, but, as already noted, it was impossible, either preoperatively or at operation, to identify the cases in which this could be expected to happen. The size of the missile was not the determining consideration. A wound caused by a small foreign body which cut a main bile channel was likely to be followed by more profuse drainage than a superficial hepatic injury of greater extent. The principle that all suspected wounds of the liver should be explored and the additional principle that all should be treated by adequate drainage were eventually established as the only sound policy in this type of injury.

TABLE 75.—*Percentage distribution of operations in 695 wounds of liver*

Operation	1944	1945	Total
Drainage only.....	48.50	87.4	57.8
Suture and drainage.....	6.50	1.8	5.3
Suture and pack.....	.95	0	.8
Pack only.....	34.10	9.6	28.2
Muscle graft.....	.15	0	.1
No treatment.....	9.80	1.2	7.8

Drainage was instituted with Penrose or cigarette drains. Two were employed if the wound was large or if there was more than one injury. The accepted practice was to place a Penrose drain lateral to the postero-inferior margin of the liver, to prevent collections of bile or pus in this region, and to use the same technique for drainage of the subhepatic space. To guard against wound infections and disruptions, the drains were not brought to the exterior through the original laparotomy or thoracolaparotomy incision. Instead, they were delivered through a dependent incision placed subcostally in the anterior or midaxillary line and preferably at least 1.5 inches long. It was found essential to extend this incision through all layers of the abdominal wall. If they were not widely opened, the drains were likely to become strangulated and their whole purpose would be defeated. In the occasional case, a debrided wound track coincided with the site of the usual subcostal incision for drainage and could be used satisfactorily for this purpose.

It was imperative to keep the drains in situ until bile drainage had ceased completely. This was usually by the 10th or 12th day, though it was sometimes considerably later. Drains were always shortened gradually, beginning on the 4th or 5th day. They were never removed abruptly in toto.

Although packing became less and less popular as a definitive method of treatment as the war progressed, the temporary use of a dry pack was occasionally extremely helpful. Active oozing from large superficial wounds of the liver could be controlled by this means while more urgent injuries were being cared for. It was unusual, when the pack was removed, not to find that bleeding had ceased and that no other measures were necessary to control it.

Relatively few wounds of the liver were sutured by surgeons of the group in the course of the war. By 1945, most of them had abandoned the practice completely, chiefly because it had been repeatedly observed that more serious bleeding might follow this procedure than had existed before it.

POSTOPERATIVE COMPLICATIONS

Not very many complications of wounds of the liver were observed in forward hospitals as compared with the number observed in hospitals farther to the rear. A report by Burford¹³ from a general hospital showed that 25, chiefly resulting from inadequate drainage, had occurred in 98 wounds of the liver. They included subphrenic abscess in 14 cases, intrahepatic abscess in 6 cases, and bile empyema in 5 cases.

The complications observed in field hospitals were what might have been expected in view of the nature of the wounds. They were chiefly presented as bile empyema or a biliary thoracic fistula. The diaphragm was obviously perforated in all thoracoabdominal wounds, which comprised 53.8 percent of the wounds of the liver. Bile and exuded fluids, if they could not drain externally because a pack had been used or for other reasons, sometimes forced their way through the sutured diaphragmatic wound, with the results just

¹³ See footnote 12, p. 277.

stated. The technique by which the diaphragm was closed seemed to have nothing to do with their occurrence. In one such case, the lung was adherent to the diaphragmatic suture line, and the erosion of a bronchus by bile created an extremely serious problem. Occasionally the bile, after it had eroded the diaphragmatic suture line and reached the pleura, caused a breakdown of the thoracotomy incision, with a resulting subphrenic pleurocutaneous fistula.

Although there was no instance in a forward hospital of a fatal secondary hemorrhage, a surgeon of the group witnessed such an accident in a general hospital after removal of a pack from the liver on the 18th postoperative day. The single instance of serious postoperative bleeding which occurred while these patients were under observation in forward hospitals is recorded in detail because of the lessons implicit in the case:

Case report.—An American soldier was admitted to a field hospital after being wounded in the right costophrenic sulcus and the hilar region of the liver by high-explosive shell fragments. The wound was extended and debrided under nitrous oxide-oxygen-ether anesthesia, and a shell fragment and several bits of clothing were removed from the liver. There was some oozing of dark blood, but the bleeding was not thought sufficient to justify any special hemostatic measures. Penrose drains were introduced and brought out through a separate drainage incision.

For 36 hours after operation, there was copious drainage of bile, but the postoperative course was otherwise uneventful until the eighth postoperative day. Then a severe hemorrhage occurred through the drainage incision. It ceased spontaneously, and there was no further bleeding until the ninth day, when a second severe hemorrhage occurred. Like the preceding hemorrhage, it was massive and obviously arterial in origin. It was checked by the insertion of a gauze pack deeply into the liver wound, through the enlarged drainage incision. A third hemorrhage 36 hours later was checked by the insertion of a fresh pack after the removal of the original pack.

Chills and fever occurred on the 16th postoperative day, while the second pack was still in situ. On the 17th day, the temperature rose to 105.8° F., and another severe hemorrhage occurred about the pack. The external wound was then opened under Pentothal anesthesia, and the wound in the liver was exposed by excision with the actual cautery for a depth of 7 cm. A large artery was found to have been partially severed by the original injury. It was clamped and ligated, and Penrose drains were inserted into the depth of the wound.

Convalescence was stormy. Severe distention developed on the 18th day (counting from the day of the first operation). On the 22d day, there was profuse biliary drainage. On the 32d day, a liver abscess was drained. On the 41st day, a pelvic abscess was drained, and on the 51st day a subhepatic abscess was drained. Thereafter recovery was satisfactory, and when the patient was evacuated on the 75th day, he was in good condition.

The hemorrhages in this case were probably all caused by repeated re-opening of the partially severed artery as the surrounding clot retracted. The insertion of the first pack, on the ninth day after operation, was perhaps justified, in an attempt to control bleeding by conservative means. In retrospect, however, it clearly would have been wiser to explore the bleeding area without delay when hemorrhage recurred; it was known that the wound was in the hilum, and the hemorrhage was so massive that extensive packing was necessary to check it. There was no local or systemic evidence of infection when this pack was applied. It seems certain, however, that the compli-

cations which followed—infection, secondary venous bleeding, hepatic abscess, subhepatic abscess, and pelvic abscess—all arose because a pack was used and drainage was thus impeded. Any one of these complications could readily have been fatal, and all might have been prevented had the secondary hemorrhage been attacked at its source when it first occurred on the eighth postoperative day.

CASE FATALITY RATES AND FACTORS OF MORTALITY

The case fatality rate in these 829 wounds of the liver, 27.0 percent (224 deaths), is to be compared with the rate of 66.3 percent reported for similar wounds in American Expeditionary Forces in World War I.¹⁴ These 829 wounds represented 27.0 percent of 3,066 abdominal injuries, in contrast to the 13.3 percent represented by comparable wounds among American soldiers in World War I (table 8, p. 93). The British proportion of wounds of the liver in that war was 16.8 percent (table 8).

Shock was responsible for 115 of the 224 fatalities in wounds of the liver, 51.3 percent of the total number of deaths. All deaths from this cause occurred before the end of the second postoperative day. When these patients were first seen, they were all in serious circulatory collapse, which persisted in spite of vigorous efforts at resuscitation. Blood loss was only one of several contributory factors; others included disturbances of cardiorespiratory physiology, overwhelming contamination of the peritoneal and pleural cavities, actual destruction of tissue, and widespread retroperitoneal cellulitis.

Pulmonary complications were the cause of 38 deaths, 17.0 percent of the total number. Trauma to the diaphragm, which occurred in over half of all wounds of the liver; trauma to the lung; contamination of the pleural cavities by bile; and the necessary prolongation of anesthesia and operation provided an ample background for this cause of death.

Peritonitis was primarily responsible for 28 deaths, 12.5 percent of the total number. It was present to some degree in all fatal cases, but it was not considered the primary cause of death unless it was widespread or took the form of a localized process, such as a subphrenic abscess.

Oliguria and renal failure were the chief causes of death in 19 cases (8.5 percent). The so-called transfusion kidney and pigment nephropathy could not be excluded as the principal lesion in these cases, but interesting possibilities obviously suggest themselves concerning the relationship between the liver damage and the renal failure.

In the remaining 24 cases, the causes of death included such conditions as gas gangrene, head injuries, and wounds of the spinal cord with paraplegia. The hepatic injury in this group usually played only a minor role in the fatal outcome.

It should be emphasized again that in no case in this series could death during the postoperative period in a forward hospital be ascribed to bleeding

¹⁴ See footnote 3, p. 276.

from the liver. In World War I, hemorrhage was the chief source of both morbidity and mortality in wounds of the liver, while in World War II, at least in the cases handled by the 2d Auxiliary Surgical Group, bile leakage and damage of the hepatic parenchyma (after shock) were the chief factors of mortality.

The source of bleeding in wounds of the liver is the hepatic artery, the hepatic vein, or the portal vein. Unless, therefore, a hilar injury has been sustained or a missile has penetrated deeply into the liver tissue, serious bleeding should not be common. The larger branches of the portal vein lie nearer the surface than the branches of the arterial system, but the pressure in the venous system is low (8 to 10 mm. Hg), and hemorrhage from them, as is clear from this series of wounds of the liver, is not difficult to control.

The change in therapeutic methods reflects this change of emphasis. In World War I, packs to control hemorrhage furnished the chief method of treatment when active treatment was undertaken at all. In World War II, active therapy was undertaken in all cases, and drainage eventually became the most popular method of treatment.

The death rate in this series undoubtedly was influenced by certain factors such as the wounding agent (p. 97), the timelag from injury to operation (p. 103), the availability of adequate shock therapy (p. 124), and the use of the sulfonamides and later of penicillin (p. 197). It is difficult, however, to reduce their influence to statistical terms. The case fatality rate was higher during the winter than the summer, probably, as in other injuries, because of the higher winter incidence of respiratory infections.

The case fatality rate was directly proportional to the number of viscera injured (table 10, fig. 22). It was 9.7 percent when only the liver was injured, but it rose to 84.6 percent when four or more other viscera were injured also.

Associated extra-abdominal injuries were chiefly compound fractures of the long bones, traumatic amputations, injuries of the head and spinal cord, and injuries of the lungs and other thoracic structures, including, occasionally, the heart. They added greatly to the morbidity of this series and undoubtedly contributed to the death rate, though it is impossible to evaluate their individual influence.

WOUNDS OF THE EXTRAHEPATIC BILIARY TRACT

The degree of damage to the gallbladder varied widely in the 51 wounds of the liver in which this organ was implicated. In one instance, the fundus was partially avulsed from its bed; but the gallbladder wall was not damaged, and simple suture was the only treatment necessary. In five cases, the wounds of the fundus were small and could be closed by purse-string suture. In the remaining cases, the damage was almost evenly divided between severe lacerations which required cholecystectomy and less severe injuries which could be treated by cholecystostomy.

One of the two patients with an injury of the common duct suffered a perforation of the hepaticoduodenal ligament; simple suture, without drainage, was followed by prompt recovery. The other had a wound of the duct near the ampulla of Vater. It was overlooked at operation, and, while the patient had other severe injuries, this error unquestionably contributed to the fatal outcome.

Because of the presence of wounds of the liver in all wounds of the extrahepatic biliary tract, it is clearly impossible to determine the influence exerted by the latter type of injury upon the case fatality rate. It was probably not very important. The rate for all wounds of the liver was 27.0 percent. For the 53 cases in which wounds of the liver were associated with injuries of the extrahepatic biliary tract, it was 30.2 percent, which is not materially different.

CHAPTER XXII

Wounds of the Pancreas (62 Casualties)

H. Leon Poole, M. D.

The pancreas was wounded less frequently than any other major abdominal organ in the 3,154 abdominal injuries treated by the 2d Auxiliary Surgical Group in 1944-45 (table 76). The low frequency, 2.0 percent, parallels other reported experiences. In World War I, there were only 5 such injuries reported by British observers¹ in a series of 965 cases (0.5 percent), and the proportion in all abdominal injuries sustained by the American Expeditionary Forces was even lower (0.2 percent).² Jolly³ reported 4 injuries of the pancreas in a series of 970 abdominal injuries observed in the Spanish Civil War.

TABLE 76.—*Essential data in 62 wounds of pancreas*

Type of wound	Cases	Frequency		Deaths	Case fatality rate
		In 3,154 abdominal injuries	In 62 pancreatic injuries		
		Percent	Percent		
Univisceral	1	0.03	1.6	1	100.0
Multivisceral	61	1.93	98.4	34	55.7
Total	62	1.97	100.0	35	56.5

The low frequency suggests that many of the patients who sustained such injuries did not survive to reach the hospital. The risk is not so much in the injury of the pancreas per se as in the almost inevitable damage to surrounding structures. This is borne out by certain facts:

1. Only 1 of the 62 injuries in this series was univisceral.
2. Thirteen of the casualties also suffered injury to a major blood vessel, in five cases the vessel being the vena cava.
3. Every patient was in shock when he was first seen.
4. The case fatality rate was 56.5 percent (35 deaths).

The precise danger inherent in a wound confined to the pancreas cannot be determined from this series, in which, as just mentioned, there was only one univisceral injury. The relative surgical inaccessibility of the pancreatic

¹ History of the Great War Based on Official Documents. Medical Services Surgery of the War. London: His Majesty's Stationery Office, 1922, vol. I.

² The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1.

³ Jolly, Douglas W.: Field Surgery in Total War. New York: Paul B. Hoeber, Inc., 1941.

region is attested by the fact that in three cases the wound was diagnosed only at autopsy.

NATURE OF INJURY

Agents causing injuries of the pancreas were of the same type, and acted with essentially the same frequency, as in other categories of abdominal injuries. Lacerations and perforations were the commonest type of wound. Penetrating wounds were present in 5 cases, and the organ was transected 3 times. In the 52 cases in which data concerning location were recorded, the head was involved 14 times, twice with involvement of the pancreatic duct also; the tail 24 times; and the body 14 times. Peritonitis caused by spill of pancreatic secretions was recorded in only one instance.

Thirty-two injuries, of which sixteen were fatal, were thoracoabdominal, and thirty, of which nineteen were fatal, were confined to the abdomen.

MULTIPLE AND ASSOCIATED INJURIES

Wounds of the pancreas were associated with wounds of other viscera in all except 1 of the 62 cases (tables 76 to 78, inclusive). The other damaged organs, in order of frequency of involvement, were the stomach, liver, spleen, kidney, colon, duodenum, and jejunum and ileum. Two or more other viscera were injured in almost three-quarters of all cases. Vascular injuries were associated in 13 cases, in every one of which other viscera were also injured.

Associated injuries, all of which were severe, were present in 16 cases (25.8 percent). Seven of these injuries were compound fractures or extensive soft-tissue wounds, and two patients had spinal-cord injuries.

TABLE 77.—*Influence of multiplicity factor on case fatality rates in 62 wounds of pancreas*

Organs injured	Cases	Deaths	Case fatality rate
Pancreas only.....	1	1	100.0
Pancreas and 1 viscus.....	15	5	33.3
Pancreas and 2 viscera.....	22	11	50.0
Pancreas and 3 viscera.....	15	9	60.0
Pancreas and 4 viscera.....	9	9	100.0
Total.....	62	35	56.5

CLINICAL FINDINGS

All 62 patients with injuries of the pancreas were in shock when they were first seen. In not a single instance were clinical findings such as to arouse suspicion that the pancreas had been injured.

TABLE 78.—*Influence of specific additional organs wounded on case fatality rates in 61 multivisceral wounds of pancreas*

Organs injured	Two organs only			Plus additional organs			Total		
	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate
Pancreas and stomach----	4	1	25. 0	33	21	63. 6	37	22	59. 5
Pancreas and duodenum----	0	0	(¹)	11	9	81. 8	11	9	81. 8
Pancreas and jejuno-ileum-----	0	0	(¹)	8	7	87. 5	8	7	87. 5
Pancreas and colon-----	3	2	66. 6	14	10	71. 4	17	12	70. 6
Pancreas and liver-----	5	2	40. 0	20	13	65. 0	25	15	60. 0
Pancreas and spleen-----	2	0	0	20	11	55. 0	22	11	50. 0
Pancreas and kidney-----	1	0	0	19	16	84. 2	20	16	80. 0
Pancreas and major vessels-----	0	0	(¹)	13	11	84. 6	13	11	84. 6

¹ Not applicable.

All the men were seen too early for the effects of digestive secretions to have become apparent upon the skin. It was not possible by clinical methods to differentiate digestive peritonitis from peritonitis caused by fecal contamination. It was impossible to identify the pancreatic secretion in the discharge from the wound because of the admixture of blood and gastrointestinal contents. Laboratory facilities were not available for such determinations as the serum amylase test for pancreatitis. The sole clue to a pancreatic wound, in short, was the anatomic site of the injury.

TREATMENT

A transdiaphragmatic approach was used in 12 of the 32 thoracoabdominal injuries, and some type of abdominal incision in the other 48 cases in which this detail was recorded. Because the pancreatic wound was of secondary importance in all but one case in the series, the approach which afforded the greatest facility in the management of the other wounded viscera was always chosen.

Drainage of the site of the pancreatic injury was the only treatment in 24 of the 59 cases in which the diagnosis was made ante mortem. The wound was sutured in 17 cases, in 11 of which drainage was instituted. Packing was employed in 5 cases, in 1 of which drainage was instituted. The other 3 cases were managed by partial pancreatectomy, in 2 instances supplemented by drainage. Ligation of the pancreatic duct was performed in 1 of the 2 cases in which this structure was injured.

In three instances, as already mentioned, the injury was overlooked and an ante mortem diagnosis was not made. Four patients died on the operating table, and in the six remaining cases it was not possible to determine from the records why no active treatment had been instituted.

POSTOPERATIVE COMPLICATIONS

Shock which was present before operation and continued afterward was not listed as a postoperative complication. When it is excluded, postoperative complications occurred in 13 cases (21.0 percent). Anuria was present in five cases. Digestive peritonitis was observed in two instances; in one the diagnosis was made at operation and in the other at autopsy. Acute pancreatitis, jaundice, gastric hemorrhage, biliary fistula from an overlooked common duct injury, pulmonary edema, pneumonia and empyema, and femoral phlebitis occurred in one case each. Pancreatic fistula and its complications were not observed in forward hospitals, the patients being evacuated before these became manifest, but the records did not mention particular difficulties from pancreatic drainage.

CASE FATALITY RATES AND FACTORS OF MORTALITY

There were 35 deaths in the 62 pancreatic wounds (56.5 percent). Four, as already noted, occurred on the operating table, and an additional 15 occurred within the first 24 hours after operation. Two patients died on the first postoperative day, three on the second, one on the third, seven between the fifth and seventh days, and three after the seventh day.

Shock, hemorrhage, or both, were the primary causes of death in 21 of the fatalities (60.0 percent). Anuria was responsible for 5 other deaths and peritonitis for 3. The other six were variously caused by pancreatitis, gastric hemorrhage, atelectasis, pulmonary edema, pneumonia, and the vagovagal reflex following bronchoscopy.

The single patient with a univisceral pancreatic injury died on the eighth postoperative day, of pneumonia and empyema. In multivisceral injuries, the case fatality rate increased progressively as additional organs were involved (table 77) and reached 100 percent in the 9 cases in which 4 were involved in addition to the pancreas.

The cause of death was not stated in 1 of the 4 patients who died on the operating table. In the other three cases, the causes were, respectively, pancreatitis, hemorrhage and shock, and hemorrhage from an injured mediastinal vessel. All three patients whose pancreatic injuries were not discovered until autopsy had other serious visceral or vascular injuries. One of these three deaths was caused by anuria, one by peritonitis caused by an unrecognized lesion of the duodenum, and one by bile peritonitis arising from an overlooked injury of the common bile duct.

There were 11 fatalities in the 13 cases associated with vascular injury (84.6 percent). All five patients with injuries of the inferior vena cava died, as did each of the patients with injuries of the duodenal and pancreatic vessels and of the lumbar artery. One of the four patients with injuries of the splenic pedicle survived, as did one of the two with injuries of the renal pedicle.

CHAPTER XXIII

Wounds of the Spleen (341 Casualties)

H. Leon Poole, M. D.

The experience of the 2d Auxiliary Surgical Group with wounds of the spleen was at some variance with previous experiences with these injuries. The frequency was greater, the proportion of multivisceral injuries was larger, and the damage to the organ was more severe than previous records showed, but the case fatality rate was lower, probably because policies of treatment, including operative approaches, were different.

Records of 3,546 abdominal wounds sustained by the American Expeditionary Forces in World War I include only 49 instances ¹ of injury to the spleen, a frequency of 1.4 percent. Bailey,² in 1942, reported only 54 splenic injuries among British troops and estimated their frequency at 5.6 percent. Jolly ³ reported a percentage of 4.6 injuries of the spleen in a series of 238 cases of abdominal injuries in the Spanish Civil War. Giblin ⁴ reported 3 splenic injuries among 90 abdominal wounds observed during the El Alamein campaign. Splenic injuries occurred in 32 cases, 5.1 percent of the total number, in the two periods covered by Ogilvie's ⁵ report in 1942 on abdominal wounds in the Western Desert.

In contrast to these figures, the surgeons of the 2d Auxiliary Surgical Group observed 341 instances of splenic injury in the 3,154 patients with abdominal injuries treated during 1944 and 1945 (10.8 percent) (table 79). This was greater than the frequency of 6.4 percent (22 of 346 abdominal injuries) recorded by the same surgeons in 1943.

Two hundred and fifty-three of the three hundred and forty-one wounds (74.2 percent) were thoracoabdominal injuries. In their entire experience from 1943 through 1945, the group surgeons treated a total of 903 thoracoabdominal injuries, in which the left diaphragm was involved 468 times. There were 277 wounds of the spleen (59.2 percent) in these 468 cases.

NATURE OF INJURY

The agents causing injury to the spleen were in general of the same type and operated with essentially the same frequency as those responsible for other abdominal injuries. Blast was recorded as the cause of three wounds. Of

¹ (1) The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1. (2) This number does not include two cases of injury to the spleen among American troops in Russia.

² Bailey, Hamilton: *Surgery of Modern Warfare*. Edinburgh: E. & S. Livingstone, 1941-42.

³ Jolly, Douglas W.: *Field Surgery in Total War*. New York: Paul B. Hoeber, Inc., 1941.

⁴ Giblin, T.: Abdominal Surgery in the Alamein Campaign. *Australian & New Zealand J. Surg.* 13:37-64, July 1943.

⁵ Ogilvie, W. H.: Abdominal Wounds in the Western Desert. *Surg., Gynec. & Obst.* 78:225-238, March 1944.

TABLE 79.—*Essential data in 341 injuries of spleen*

Type of wound	Cases	Frequency		Deaths	Case fatality rate
		In 3,154 abdominal injuries	In 341 splenic injuries		
		<i>Percent</i>	<i>Percent</i>		
Univisceral.....	100	3.2	29.3	12	12.0
Multivisceral.....	241	7.6	70.7	73	30.3
Total cases.....	341	10.8	100.0	85	24.9
Thoracoabdominal.....	253	8.0	74.2	67	26.5
Abdominal.....	88	2.8	25.8	18	20.5
Total cases.....	341	10.8	100.0	85	24.9

the 3 non-battle-incurred injuries in the series, 2 were the result of accidental falls and 1 the result of a vehicular accident.

All degrees of damage were present after wounding, ranging from small fissures to complete fragmentation of the body of the spleen. In a few instances, the organ was penetrated. Severe lacerations, penetrations, and perforations produced essentially the same gross lesions as a splenic fracture; that is, irregular rents in the capsule radiating from the track of the causative agent. Injury to the splenic pedicle, without injury to the body of the organ, occurred 8 times and subcapsular hematoma 3 times. From the standpoint of degree, the injuries were classified as severe in 61.3 percent of the cases, as moderate in 29.3 percent, and as slight in only 9.4 percent.

Active hemorrhage from the injured spleen was only occasionally encountered when the abdomen was opened. In these cases, either the pedicle was injured or the body of the organ was seriously damaged. Unless, however, the injury was slight, there was always evidence of previous hemorrhage, and active bleeding usually recurred during the maneuvers incidental to splenectomy. In some instances of thoracosplenic injury in which very little blood was encountered in the peritoneal cavity, an extensive left-sided hemothorax was present. The finding was so commonly associated with injuries of the spleen, in fact, that their presence was suspected whenever a large hemothorax was present in association with missile wounds in the lower portion of the left chest. This phenomenon was probably the result of negative intrapleural pressure, which caused the blood in the upper abdomen to be sucked up through the diaphragmatic rent.

Multivisceral and associated injuries.—One hundred of the three hundred and forty-one wounds of the spleen (29.3 percent) were univisceral (table 79). Eighty-two of these occurred in thoracoabdominal injuries. The proportion

of univisceral injuries is lower than that reported in other wars. One-third of the 49 splenic injuries recorded among American Expeditionary Forces in World War I were univisceral,⁶ as were 59.2 percent of the 54 cases reported among British troops by Bailey⁷ in 1942. Jolly,⁸ while citing no exact figures, stated that univisceral injuries were "rare" in the Spanish Civil War. Ten of the twenty-two injuries of the spleen treated by the 2d Auxiliary Surgical Group in 1943 were univisceral.

The 241 multivisceral injuries of the spleen in this series were chiefly associated with wounds of the stomach (100 cases), the colon (92 cases), the left kidney (84 cases), the small intestine (53 cases), the liver (50 cases), and the pancreas (22 cases). The jejunum was most frequently involved in wounds of the small intestine, the duodenum being injured only three times. The most commonly involved portions of the colon were the splenic flexure, the left transverse colon, and the upper portion of the descending colon. In a number of instances, two separate portions of the colon were injured.

Other structures were injured with much less frequency. The adrenal gland was injured in three cases and the gallbladder once. Major vascular channels, including the gastroepiploic artery, the left renal vein, the celiac axis, and the thoracic aorta, were involved in four instances. A second wounding agent had made a separate entry in each of the three cases in which the urinary bladder, the sigmoid colon, and the rectum were also injured.

Severe associated injuries, which were themselves multiple in 20 instances, occurred in 128 cases (34.6 percent). The most important were as follows: 53 soft-tissue injuries with 14 deaths, 36 compound fractures with 10 deaths, 13 spinal cord injuries with 6 deaths, and 6 amputations with 1 death. These injuries were often so severe that they contributed materially to the development of shock prior to surgery and to the development of complications after operation.

CLINICAL CONSIDERATIONS

Shock was an extremely common clinical finding in injuries of the spleen (table 80). Its absence, however, could not be taken to indicate that the spleen was not involved in the injury. It was mentioned as not present when the patient was first seen in 78 of 319 recorded cases (24.4 percent), in 48 of which the injury was multivisceral. Mild shock was present in 13.5 percent of the injuries and moderate or severe shock in 62.1 percent.

Tenderness and muscle defense in the left upper quadrant of the abdomen were always present in splenic injury. Pain referred to the left shoulder and to the base of the neck was observed in a few cases. The frequency of extensive left-sided hemothorax has already been commented on.

⁶ See footnote 1, p. 291.

⁷ See footnote 2, p. 291.

⁸ See footnote 3, p. 291.

TABLE 80.—*Influence of degree of shock and type of wound on case fatality rates in 319 injuries of spleen*¹

Degree of shock	Univisceral wounds			Multivisceral wounds			Total		
	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate
None.....	30	1	3.3	48	2	4.2	78	3	3.8
Mild.....	18	1	5.6	25	5	20.0	43	6	14.0
Moderate.....	29	3	10.3	66	15	22.7	95	18	18.9
Severe.....	16	7	43.8	87	49	56.3	103	56	54.4
Total.....	93	12	12.9	226	71	31.4	319	83	26.0

¹ These data are missing in 22 cases.

TREATMENT

The "surgical abstention" practiced in World War I was never seriously considered as a method of treatment for wounds of the spleen managed in World War II by the 2d Auxiliary Surgical Group. It was the general opinion that splenectomy was the procedure of choice in all cases and that it was imperative in every injury of more than minimal severity. It was performed in 299 of the 341 wounds in this series (87.7 percent) (table 81), in 9 instances with supplemental drainage.

Three of the forty-one patients in whom splenectomy was not performed died on the operating table, before the operation could be completed. In one severe injury in which the splenic vein was severed, surgery was limited to ligation of the vein. In 12 cases (table 81) in which the injury was not severe, drainage, pack, or suture was considered sufficient. In the majority of these cases, though not in all, the lesion consisted merely of a small fissure, with no active hemorrhage and little or no evidence of previous hemorrhage. In the remaining cases, the other visceral injuries or the associated injuries were of such severity that they took precedence over the splenic injury, or it was thought that the addition of splenectomy to the procedures already accomplished would be beyond the limits of the patient's tolerance.

Suture of the spleen, which was carried out in seven cases, proved an inadequate and unsatisfactory measure for the control of active hemorrhage, the prevention of subsequent hemorrhage, and the repair of damage to the spleen; the risk of secondary hemorrhage, in fact, was substantial. Moreover, this measure was as time consuming as splenectomy. The supplementary use of a muscle strip, which was employed in one case, was no more effective than simple suture. Packing of the spleen also proved an ineffective method of management.

Modern hemostatic agents such as absorbable gelatin sponges were available in overseas theaters during World War II only in limited quantities and

for designated purposes. If the situation had been different, the necessity for the removal of only slightly damaged spleens might have been prevented.

TABLE 81.—*Methods of treatment in 340 injuries of spleen*¹

Methods of treatment	Type of wound		Total
	Thoraco-abdominal	Abdominal	
Splenectomy:			
Cases.....	224	75	299
Deaths.....	60	13	73
Case fatality rate.....	26.8	17.3	24.4
Other measures:			
Cases.....	29	12	41
Drainage only.....	1	2	3
Pack.....	1	1	2
Suture.....	6	1	7
No operation on spleen ²	21	8	29
Deaths.....	7	5	12
Case fatality rate.....	24.1	41.7	29.3

¹ The record of 1 patient who died on the operating table does not make clear what had been accomplished when death occurred.

² In the 29 cases in this group, the wound of the spleen, for various reasons, was not attacked. Twenty-one of the operations were performed through a thoracoabdominal incision.

Surgical approach.—The surgical approach to injuries of the spleen in this series (table 82) differed materially from the techniques employed in previously reported series. The most striking departure from earlier methods was the frequent use of a transdiaphragmatic incision in thoracoabdominal wounds. This approach was used in 171 cases, 67.6 percent of the 253 thoracoabdominal injuries and 50.1 percent of the 341 injuries which make up the total series of wounds of the spleen. In the other 82 thoracoabdominal injuries, the abdominal approach was employed in 75 cases (29.6 percent), and both thoracic and abdominal incisions were used in the other 7 cases. Since thoracoabdominal wounds furnished almost three-quarters of the wounds of the spleen, it is not surprising to find that the transthoracic approach was used in so large a proportion of the cases. Anesthesia is an important consideration in this technique, but the ready availability of competent anesthetists, who were provided with adequate equipment, prevented any difficulties in that respect.

The case fatality rates for the transdiaphragmatic and abdominal approaches to thoracoabdominal injuries of the spleen, 19.9 percent against 41.3 percent, are so greatly in favor of the transdiaphragmatic approach as to suggest that all the advantages lay with it. Actually, the marked disparity in the figures should not be interpreted as furnishing a true appraisal of the respective rates by the two techniques. Rather, the lower rate for the transdiaphragmatic

TABLE 82.—*Surgical approaches in 337 wounds of spleen*¹

Surgical approach	Type of injury						Total		
	Thoracoabdominal			Abdominal only					
	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate	Cases	Deaths	Case fatality rate
Transdiaphragmatic	171	34	19.9	0	0	0	171	34	19.9
Abdominal	75	31	41.3	84	18	21.4	159	49	30.8
Transdiaphragmatic and abdominal	7	2	28.6	0	0	0	7	2	28.6
Total	253	67	26.5	84	18	21.4	337	85	25.2

¹ This information is lacking in 4 cases.

approach is a reflection of the feasibility and ease of intimate surgical exploration of the left upper abdominal quadrant by this incision in appropriate cases. In many of the thoracoabdominal injuries involving the spleen handled by the abdominal route, the multiplicity and location of the visceral injuries made approach from below mandatory. A number of cases showed that it was questionable wisdom to repair the diaphragm from below under these circumstances, although some surgeons followed this plan, on the ground that in a very sick patient it might be better to proceed with celiotomy, in the hope of avoiding two major incisions.

In spite of the advantages of transdiaphragmatic incision in the management of thoracoabdominal injuries involving the spleen, this approach was not used when the thorax was not involved in the wound, for two reasons:

1. It was seldom possible before operation to exclude the presence of other intraperitoneal injuries which could not be properly explored and repaired through the diaphragm.

2. When wounds of the stomach, small intestine, or colon complicated the splenic injury, there was always a risk of contaminating an undamaged pleural cavity during the transdiaphragmatic repair of the gastrointestinal wounds.

Although surgeons were in general agreement, as already mentioned, that the transdiaphragmatic approach was not the best technique for injuries of the spleen confined to the abdomen, there was no agreement as to how this type of injury should be approached. The left rectus and left paramedian incisions were most frequently used. Occasionally the one or the other was extended to the left, but as a rule splenectomy, as well as other operations in the left upper quadrant and other parts of the abdomen, could be accomplished through the original incision. The left subcostal incision and certain transverse incisions also proved satisfactory for splenectomy, though their usefulness

was limited by the possibility of other visceral injuries and the fact that full exploration of the peritoneal cavity was difficult or actually impossible through any of them. An additional serious objection, in view of the many instances in which injury to the large bowel complicated the splenic injury, was the fact that all of these incisions utilize the space best adapted for exteriorization of the colon.

POSTOPERATIVE COMPLICATIONS

Although the records of 69 patients, 20.2 percent of the total number, were incomplete, it was possible to determine indirectly, from various sources, that a large proportion of this group was evacuated without the development of postoperative complications. Aside from peritonitis and shock, which were present alone or in combination in many cases at operation, major complications were recorded in 21.0 percent of the 341 splenic injuries. Anuria, wound infection, and atelectasis were the most frequent. Portal thrombosis and secondary hemorrhage from the spleen or splenic pedicle apparently did not occur. There was also no mention of accidental injury to the pancreas or stomach incurred during the operative procedure. Among miscellaneous complications were malaria (3 instances); intestinal obstruction, pneumothorax, anaerobic infection, and psychosis (2 instances each); massive gastric hemorrhage, paroxysmal tachycardia, femoral phlebitis, pelvic abscess, jaundice, decubitus ulcer, cardiac failure, spinal meningitis, pulmonary edema, transfusion reaction, and breakdown of the diaphragmatic repair (1 instance each).

Anuria occurred only in patients who had been in severe shock before or during operation or at both times, or who had received large amounts of blood. Eight of the nine instances of atelectasis occurred in patients with thoraco-abdominal injuries. Two of the three patients with infections of the left subphrenic space had complicating injuries of the colon. All three instances of pulmonary embolism were fatal. The first occurred in a patient with a univisceral injury of the spleen. The second patient also had a compound fracture of the femur on one side and a traumatic amputation of the leg on the other. The third had severe complicating injuries of the stomach and liver.

CASE FATALITY RATES

The case fatality rate of 24.9 percent (85 cases) in these 341 injuries of the spleen is considerably lower than the 66.7 percent reported by Giblin⁹ in 1943 from El Alamein, the 50 percent reported by Ogilvie¹⁰ in his combined series from the Western Desert in 1944, and the 67 percent reported in American troops in World War I.¹¹

It is also lower than the 33.3-percent rate reported by the surgeons of the 2d Auxiliary Surgical Group in 1943. Except for the latter series and Ogilvie's

⁹ See footnote 4, p. 291.

¹⁰ See footnote 5, p. 291.

¹¹ See footnote 1 (1), p. 291.

series, it is not clear whether the figures cited do or do not include postevacuation studies.

Bailey¹² estimated that the case fatality rate in the univisceral wounds of the spleen in his series was 40 percent. In World War I, the British rate for univisceral injuries was 50 percent and for multivisceral injuries 60 percent.¹³ In the 2d Auxiliary Surgical Group series, these respective rates were 12.0 and 30.3 percent. The rate rose progressively and rapidly as the number of complicating visceral injuries increased, reaching 61.5 percent when three or more organs were involved in addition to the spleen. The case fatality rate of 24.4 percent following splenectomy in this series is to be compared with the "practically 100 percent" reported for this procedure in World War I.¹⁴

Death occurred on the operating table in 10 of 67 patients submitted to splenectomy and occurred in the first 24 hours after operation in 23 others (table 83). Three other patients died on the operating table before splenectomy could be performed.

TABLE 83.—Primary cause of death and time of death in 67 fatalities following splenectomy

Cause	On operating table	To 12 hours	12 to 24 hours	1st day	2d through 3d days	4th through 7th days	After 7th day	Total
Shock.....	7	13	8	6	4	0	0	38
Anuria.....	0	0	0	0	6	5	1	12
Peritonitis.....	0	0	1	0	1	2	1	5
Pulmonary embolism.....	0	0	0	0	2	1	0	3
Pneumonia.....	0	0	0	0	0	1	0	1
Atelectasis.....	0	0	0	1	0	0	0	1
Other.....	3	1	0	0	1	2	0	7
Total.....	10	14	9	7	14	11	2	67

In comparing the case fatality rate (table 81) for splenectomized patients (24.4 percent) with the rate for nonsplenectomized patients (29.3 percent), it must be borne in mind that in most of the latter group operation was omitted because the splenic wound was not considered serious. In nine cases, however, either severe multivisceral or severe associated injuries, or both, contraindicated additional surgery, or the complications which caused death could not be attributed solely to wounds of the spleen.

Shock was the primary cause of death in 38 splenectomized patients (table 83) and in 6 others in whom splenectomy was not performed. Peritonitis,

¹² See footnote 2, p. 291.

¹³ History of the Great War Based on Official Documents. Medical Services Surgery of the War. London: His Majesty's Stationery Office, 1922, vol. I.

¹⁴ See footnote 1 (1), p. 291.

pneumonia, and atelectasis were responsible for one death each in the non-splenectomized patients. In the remaining cases in this group, the cause of death was either undetermined or unrecorded.

Additional complications in the fatal cases included the vagovagal reflex after bronchoscopy, transfusion reaction, spinal meningitis, massive empyema, bilateral hemothorax, gastric hemorrhage, and disruption of the diaphragmatic repair complicated by atelectasis and by herniation of the stomach and colon into the chest.

CHAPTER XXIV

Wounds of the Kidney (427 Casualties)

Walter L. Byers, M.D.

Wounds of the kidney occurred in 427 (13.5 percent) of the 3,154 abdominal injuries treated by teams of the 2d Auxiliary Surgical Group during 1944 and 1945 (table 84). The official history of the American participation in World War I ¹ lists the frequency of renal injuries in that war as 6.3 percent, which is slightly higher than the 5.4 percent reported by Young in his Practice of Urology ² (table 85).

TABLE 84.—*Essential data in 427 wounds of kidney*

Type of wound	Cases	Frequency		Deaths	Case fatality rate
		In 3,154 abdominal injuries	In 427 renal injuries		
		<i>Percent</i>	<i>Percent</i>		
Univisceral.....	56	1. 8	13. 1	9	16. 1
Multivisceral.....	371	11. 8	86. 9	146	39. 4
Thoracoabdominal.....	147	4. 7	34. 4	67	45. 6
Abdominal.....	280	8. 9	65. 6	88	31. 4
Total.....	427	13. 5	100. 0	155	36. 3

In all but 56 cases, the renal wounds were multivisceral (table 84). The colon (211 cases), the liver (168 cases), the small intestine (105 cases), and the stomach (67 cases) were most frequently involved. It is a matter of technical interest that 37 of the 105 wounds of the small intestine occurred in the duodenum in association with wounds of the right kidney, and that the pancreas was wounded 20 times in association with wounds of one kidney or the other. The ureter was damaged along with the kidney in 5 cases and the bladder in 8 cases. Approximately a third of all wounds of the kidney were thoracoabdominal (table 84).

¹ The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1.

² Young, Hugh H.; and Davis, David M.: *Young's Practice of Urology*. Philadelphia: W. B. Saunders Co., 1926.

TABLE 85.—*Comparative distribution of wounds of kidney in various recorded series of abdominal injuries*

Source	Total series	Renal injuries	Frequency
			<i>Percent</i>
World War I, American (Young) ¹ -----	2, 385	129	5. 4
World War I, British ² -----	965	73	7. 6
Spanish Civil War ³ -----	238	19	8. 0
2d Auxiliary Surgical Group-----	3, 154	427	13. 5

¹ Young, Hugh H.; and Davis, David M.: *Young's Practice of Urology*. Philadelphia: W. B. Saunders Co., 1926.

² The British figures are from *War Surgery of the Abdomen*, by Cuthbert Wallace (London: J. & A. Churchill, 1918).

³ The Spanish Civil War figures were reported by Douglas W. Jolly in *Field Surgery in Total War* (New York: Paul B. Hoeber, Inc., 1941).

ANATOMIC CONSIDERATIONS

The anatomy of the kidney is such that the organ possesses both advantages and disadvantages in respect to vulnerability to battle-incurred injuries. It is well protected within the body by adipose tissue, muscle, bone, and the visceral structures of the abdomen and chest. It is also conceivable that perirenal adipose tissue may cushion the blow from a missile; it was noted several times in this series that in injuries which had resulted in extensive fragmentation of the liver or the spleen, only perforation or segmental destruction of the kidney had occurred. On the other hand, the kidney bears such a close anatomic relationship to adjacent and nearby structures that any injury in this area was likely to result in renal involvement, while any injury of the kidney was likely to be accompanied by damage to other viscera from the same missile.

Examination of the autopsy records in this group of cases revealed no instances of renal agenesis or of fused or horseshoe kidney. Cystoscopy and urography were not feasible in forward areas, but the possibility that nephrectomy might be performed for a renal injury on one side upon a patient with agenesis of the opposite kidney was constantly borne in mind, and in every case an effort was made by roentgenologic examination to distinguish the renal shadow on the uninjured side before operation was undertaken.

NATURE OF THE INJURY

In the 399 cases in which these data were recorded, 284 injuries (71.2 percent) were caused by fragmentation missiles, including all types of grenades, artillery shells, land mines, boobytraps, and bombs. Small-arms fire accounted for the remaining cases.

For convenience of discussion, wounds of the kidney may be classified under two headings, those involving the renal hilum and those involving the renal parenchyma.

Injuries of the hilum.—There were only 16 wounds of the hilar structures

in this series, with 9 deaths, all of them after nephrectomy. In 15 cases, the injury was either a laceration or a complete severance of the renal vessels, in 2 instances complicated by damage to the inferior vena cava. In one of these cases, the inferior vena cava was completely transected and the patient died in the course of operation. In the other, repair of the laceration proved impossible, and the vein had to be ligated; the patient was evacuated in good condition on the ninth day, with apparently normal urinary volume. In another case, a laceration of the renal vein was overlooked, and death occurred from continued hemorrhage. In the only hilar injury in which the renal vessels were not damaged, a laceration of the pelvis was repaired with a single interrupted suture, and recovery was uneventful.

The very small number of wounds of the renal vessels observed in forward hospitals suggests that casualties with such injuries, particularly if other major abdominal blood vessels were also injured, did not usually survive long enough to be submitted to surgery.

Injuries of the parenchyma.—Injuries of the renal parenchyma ranged from neatly drilled holes to complete disintegration of the tissues. The size of the missile and its velocity were directly responsible for the degree of destruction, but otherwise there was no apparent relationship between the type of missile and the character of the wound. A hematoma of variable size was practically always present in the perirenal area, and the wound was usually covered with an irregular clot which was rather firmly adherent to its edges. Active bleeding from the renal wound was not a constant finding, even in the event of destruction of large sections of one pole or the other, but attempts at operation to dislodge the clot from the wound usually resulted in renewed bleeding from the wound surface. Cortical hemorrhage had frequently caused separation of the tunica fibrosa, sometimes of considerable extent, with varying degrees of disturbance of the anatomic relationship of the capsule to the cortex. During mobilization of the parts, the surgeon often unwittingly perforated the distended capsule, so that a subcapsular dissection was actually performed.

CLINICAL CONSIDERATIONS

The chief symptoms and signs in wounds of the kidney were tenderness, guarding of the muscles of the flank, and hematuria. A retroperitoneal hematoma could occasionally be palpated through the flank and abdomen, but muscle guarding frequently made deep palpation difficult or impossible. In the multivisceral injuries which comprised the bulk of these renal injuries (table 84), the predominance of intraperitoneal symptoms and signs arising from wounds of other viscera was likely to overshadow the symptoms and signs of renal injury. Hemoperitoneum and peritoneal contamination, because of the resulting muscle guarding, added to the difficulties of satisfactory abdominal palpation. When pain was present, it was commonly referred to the abdomen. There was apparently no case in this series in which it was referred in the classic manner along the course of the ureter to the groin or the scrotum.

A wound of the renal parenchyma alone did not always elicit a particularly severe general reaction, and shock might be either mild or absent. In some cases, however, chiefly of injury to the renal vessels and of other viscera, shock was so deep that physical findings obtained by palpation were totally unreliable until resuscitation therapy had begun to be effective.

DIAGNOSIS

The two most important diagnostic evidences of renal damage were the location of the wound and the presence of hematuria. The physical findings, as already noted, were relatively slight insofar as localization to the kidney was concerned, and were also likely to be confused by the reaction of other viscera to injuries.

Close inspection of the wound was often useful in determining what structures were involved. It was always helpful, particularly in penetrating wounds, if the patient could describe his position at the time of wounding or knew the direction from which the missile had come. In univisceral wounds, the causative missile was likely to be traveling at low velocity; the fragment was therefore likely to be found in the kidney or adjacent to it when the wound was explored. At other times, the angle of penetration was such that only the kidney was wounded. In thoracoabdominal wounds, the usual direction of penetration was posteriorly and posterolaterally from the chest into the abdomen. The costophrenic angle was frequently involved. The size of the wounds of entrance and exit was never an index of the extent of damage to the kidney.

It was sometimes possible, by careful inspection, to detect some disparity in the appearance of the flanks, but no difference was likely to be observed unless there had been considerable destruction of tissue or a hematoma of considerable size was present. Bleeding from wounds of the flank and loin did not necessarily point to hilar damage. The renal parenchyma can bleed vigorously, and intraperitoneal blood can also escape from a wound in the flank.

Although a wound into the pelvis provided a direct communication from the kidney to the exterior surface of the body, attempts to identify urine in the wound or about the kidney were seldom successful. Catheterization was practically always necessary to recover urine specimens. The absence of blood could not be assumed until the bladder was completely emptied. It was not unusual for the first portion of the catheterized specimen to be clear and the last portion to be grossly discolored with blood, especially if there had been a long timelag since wounding.

Roentgenologic examination in forward units was limited to flat films and fluoroscopy; stereoscopy, retrograde pyelography, intravenous urography, and similar diagnostic refinements were not practical under field conditions. Moreover, retrograde pyelography was regarded as undesirable because cystoscopy is sometimes attended with some degree of shock. If shock from this cause had been superimposed on shock from wounding, a seriously wounded casualty might conceivably have been placed in still further jeopardy.

TREATMENT

Specific treatment was deliberately withheld in 8 of the 427 renal injuries, because it was not regarded as necessary. It was not instituted in 3 other cases, because the renal wound was overlooked. The remaining cases were chiefly managed by nephrectomy or by drainage only.

Surgical approach.—An abdominal transperitoneal approach was employed in 259 (61.7 percent) of the 420 injuries in which the type of incision was listed because it was necessary in these cases to expose abdominal viscera along with the kidney. The risk of retroperitoneal contamination inherent in this approach was fully realized, but the objection was regarded as less valid than under other circumstances, because of the probability that contamination was already present as the result of the original wound. A combined abdominal-flank incision might have been more desirable, but it was not employed, chiefly because of the added time it would have required.

Thoracotomy was employed in 64 (43.5 percent) of the 147 wounds of the kidney in which the thorax was wounded also. This transdiaphragmatic approach to the abdomen and retroperitoneal area proved convenient, and when it was employed on proper indications the results were good. In 40 cases, separate incisions were made into the thorax and into the abdomen; in 39, the approach was transabdominal; and in 3, the injury was approached through the flank. In the remaining case, the renal injury was overlooked.

The flank or loin incision was found preferable for wounds limited to the upper quadrants of the abdomen. This approach provided excellent exposure and had the added advantage that the incision could be extended antero-medially for laparotomy and for necessary operations on the abdominal viscera. It practically always healed by primary intention. This was not, however, a desirable incision when the large bowel was also injured, since it interfered with proper exteriorization of the colon.

Procedures.—Nephrectomy was performed in 120 of the 427 renal injuries (28.1 percent). It was employed in 16 cases because of damage to the renal artery and vein and was used in the other cases because of extensive destruction of the renal parenchyma. A less radical procedure was always chosen when it was practical, but damage to the renal vessels, extensive destruction of the renal parenchyma, and widespread fracture of the kidney with destruction of the blood supply to the segments frequently left the surgeon with no other choice.

Drainage was the only procedure in 285 cases (66.7 percent of the total number). It was also carried out in association with other procedures in 134 other cases (all but 8 of the renal injuries treated by other surgical measures). It was conveniently accomplished by soft rubber material of the Penrose type, with or without a wick. If the original wound was not suitably located, drainage was instituted through a separate stab wound. Otherwise, debrided missile tracks in the flank or loin were utilized for this purpose. Complete debridement was the rule before drainage was instituted.

Resection and suture, which were used in only seven cases, were not popular in the 2d Auxiliary Surgical Group, probably for the reason brought to light by autopsy in the single fatal case in which the method was used. The notation read: "During the 3-day interval between surgery and death, the sutures had become buried in the swollen renal parenchyma, while the areas included were dark, and engorged with blood on section."

Packing was employed three times. This was another method not highly regarded, and control of hemorrhage by other measures was preferred, for obvious reasons. Because firm pressure is necessary to accomplish hemostasis, the gauze had to be packed firmly from the renal fascia to the skin level, and the immediate consequence was inhibition of drainage in an area already potentially, if not actually, infected. Furthermore, fresh bleeding was always a possibility when the pack was removed.

Capsulotomy was employed in one case in the series. Nephrostomy was not employed at all.

Suture material.—Ordinary types of suture material proved satisfactory for all procedures on the kidney except segmental resections and repair of fractures of the parenchyma. The inclusion of ribbon suture material in the tables of equipment for forward hospitals would have been an incentive to even further conservatism and might have made unnecessary a few of the nephrectomies which were performed.

POSTOPERATIVE MANAGEMENT

Drains were left in place as long as there was significant soiling of the dressings, which was usually 7 to 10 days. Dressings over a large wound in the flank through which drainage of the renal fossa had been established had to be changed several times daily. The repeated removal of adhesive tape caused skin irritation, and the entire task proved too time consuming for busy nurses. Another type of dressing was therefore devised. The wound was covered with a few sterile gauze sponges reenforced by one or two abdominal pads, all held in place by a large bath towel which encircled the abdomen and was secured anteriorly with safety pins. With this method, changes of dressings could be quickly and easily accomplished, and excoriation of the skin by adhesive tape was entirely avoided.

An extremely important phase of the postoperative management of renal wounds was an adequate fluid intake, ranging from 2,000 to 3,000 cc. daily by mouth or parenterally. Otherwise, the postoperative routine did not differ from the usual routine for abdominal wounds.

POSTOPERATIVE COMPLICATIONS

Sepsis seldom occurred in wounds of the kidney, except in association with perforation of the retroperitoneal portion of the colon. It was guarded against by thorough debridement of the wound, with excision of dead tissue, free blood, bits of clothing and metallic foreign bodies, and by adequate drain-

age. Secondary hemorrhage does not seem to have occurred in any case in the series.

Because urinary fistulas seldom occur in renal injuries except after wounding of the parenchyma with involvement of the renal pelvis, they were not common in this series. Pocketing of the urine as the result of inadequate drainage also was uncommon. When it did occur, it was accompanied by a febrile reaction, and the patient's condition did not improve until adequate drainage was established. Urine was often noted on the dressings, but as a rule, urinary drainage ceased spontaneously after a few days. Nephrostomy, as already noted, was not performed in any case in the series.

FACTORS OF MORTALITY

As would be expected, the case fatality rate in wounds of the kidney depended upon whether they were univisceral or multivisceral (table 84). The multiplicity factor proved as important from the standpoint of prognosis as it proved in all other regional injuries (table 10, fig. 22).

Seventeen of the fifty-six univisceral injuries were treated by nephrectomy, with four deaths. One occurred from shock 20 minutes after the operation was concluded. The second was the result of anaphylactic shock. It occurred on the seventh postoperative day, immediately after the intravenous infusion of 100 cc. of Alsever's solution. The third patient died of anuria. The fourth died of ascending myelitis from an associated injury of the spinal cord.

There were 49 deaths (47.6 percent) in the 103 nephrectomies performed in the multivisceral injuries. This case fatality rate is to be compared with the 44.2-percent rate for nephrectomy in the whole series (53 of 120 operations).

The time of death could be determined from the records in 149 of the 155 fatal cases. It occurred within the first 72 hours after operation in 120 cases (80.5 percent). The great majority of these patients had sustained wounds which were essentially lethal, and their deaths were attributable to shock.

CHAPTER XXV

Wounds of the Ureter (27 Casualties)

Walter L. Byers, M. D.

There were only 27 wounds of the ureter (0.86 percent) in the 3,154 abdominal injuries in this series. Only 4 ureteral injuries are listed in the records of the American Expeditionary Forces in World War I.¹ They constituted 0.1 percent of all abdominal and pelvic injuries.

The single univisceral injury of the ureter treated by the 2d Auxiliary Surgical Group surgeons was caused by a shell fragment which produced a small laceration of the upper portion. In the 26 multivisceral wounds, the small intestine was involved 21 times and the large intestine 18 times. Injuries to these two structures represented more than half of the coincidental injuries. The bladder and liver were each involved 6 times; the kidney 5 times; the duodenum, extraperitoneal rectum, and great vessels of the abdomen 4 times each; and the stomach and spleen twice each. The internal iliac vein was the largest vessel involved in the complicating vascular injuries.

DIAGNOSIS

The preoperative diagnosis of ureteral injuries was not easy, particularly when other structures within the abdomen were also injured, as they were in all but one case in this series. Hematuria was not pathognomonic; it was present in only three cases in which the bladder or a kidney was not also damaged. In no instance in the series was there a detectable amount of urine on the dressing or about the wound. The explanation, at least in part, was shock; it was frequent in these patients, and it was usually accompanied by oliguria or anuria. As a result, there was no telltale urinary leakage to lead to suspicion of a ureteral wound.

Facilities for cystoscopy, intravenous urography, and ureteral catheterization, as noted in the previous chapter, were not available in field hospitals. Even if they had been, most of these casualties, because of the gravity of their injuries, would not have been suitable candidates for such diagnostic procedures. Accordingly, the usual diagnostic refinements of urologic surgery had to be dispensed with.

As a result of these various circumstances, the diagnosis of ureteral injury was usually made only at operation, and even then was overlooked in 3 of the 27 cases.

¹ The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1.

TREATMENT

It was the accepted practice to expose the ureter fully whenever a missile had passed anywhere along its course. Exposure was often difficult because of the retroperitoneal hemorrhage common in such injuries. When leakage from a wounded colon was also present, technical difficulties were still greater. These difficulties explain the fact already mentioned; namely, that the ureteral wound was overlooked at operation in three cases. In one of the overlooked cases, drainage was instituted because of a wound in the retroperitoneal portion of the colon, but the ureteral injury was not found until autopsy.

In the 24 cases in which ureteral damage was identified at operation, seven separate surgical techniques were employed, as follows:

Transplantation of the ureter into the bladder was performed in six cases. This procedure could be utilized only in wounds of the distal ureter. In one instance, the suture line separated on the third postoperative day but was successfully repaired.

Ureteroanastomosis was performed six times. Four of the operations were done by the telescoping technique, with one failure, as manifested by postoperative urinary drainage. The two patients treated by end-to-end anastomosis died within 48 hours of operation. Both fatalities were caused by shock and were not attributable to the ureteral injuries.

Nephrectomy was performed five times, in each instance because of extensive renal damage. In no case was the injury to the proximal ureter of clinical significance in comparison to the wound of the kidney.

Ligation of the ureter at both ends was carried out in three transecting wounds, with extensive loss of substance. In one of these cases, the kidney was also wounded.

Ureteral lacerations were successfully sutured in two cases. One case was managed by drainage only. Cutaneous ureterostomy was done in one case; destruction of a considerable segment did not permit repair, and the condition of the patient did not warrant extension of the operating time to perform nephrostomy. The latter procedure was not employed in any of these ureteral injuries, though in retrospect it seems that it might have been useful in certain cases.

The small number of ureteral injuries and the various procedures used in their management make the discussion of any special technique of no value.

FACTORS OF MORTALITY

The 11 deaths in these 27 ureteral injuries all occurred in patients with multivisceral wounds. The 8 deaths which occurred within 72 hours of wounding were attributed to shock. There were 2 fatalities in the 4 multivisceral injuries in which the great vessels were involved. One patient died 48 hours after operation, from multiple pulmonary emboli, and the other on the seventh postoperative day, of generalized peritonitis. The ureteral repair

did not break down in either instance. The cause of death was not clear in one case.

In the three cases in which ureteral injuries were overlooked at operation, the error was assigned an important contributory role, though not the primary role, in the fatal outcome.

CHAPTER XXVI

Wounds of the Urinary Bladder (155 Casualties)

Leon M. Michels, M. D.

There were 155 wounds of the urinary bladder (4.9 percent) in the 3,154 abdominal injuries in this series (table 86). One hundred and thirty-four were multivisceral; some portion of the intestinal tract as well as the bladder was wounded in every one of these cases.

TABLE 86.—*Essential data in 155 wounds of urinary bladder*

Type of wound	Cases	Frequency		Deaths	Case fatality rate
		In 3,154 abdominal injuries	In 155 bladder injuries		
Univisceral.....	21	Percent 0. 67	Percent 13. 5	0	0
Multivisceral.....	134	4. 25	86. 5	46	34. 3
Total.....	155	4. 91	100. 0	46	29. 7

NATURE OF THE INJURY

The most frequent sites of entry of missiles causing wounds of the bladder were the buttocks and the anterior abdominal wall. Each of these sites was penetrated 56 times. Other sites of entry were the thigh, hip, perineum, back, flank, and, in one instance, the midaxilla. The missiles were retained in the body in about two-thirds of the cases. Thirty-five wounds were caused by bullets, seventy-one by shell fragments, and three by blunt trauma. In the remaining cases, the wounding agent was not recorded.

The wound was an intraperitoneal laceration of the bladder in 137 cases an extraperitoneal laceration in 9 cases, and a severe contusion without laceration in 9 cases.

CLINICAL CONSIDERATIONS

The physical findings in bladder injuries were not pathognomonic. Tenderness, rigidity, and the presence or absence of peristalsis depended chiefly upon complicating intra-abdominal wounds and the amount of intra-abdominal or retroperitoneal hemorrhage. Discharge of urine through the abdominal wound was observed in 6 cases, and hematuria was present in 150 cases. Both

findings pointed to injury of some portion of the urinary tract but did not necessarily implicate the bladder.

Diagnosis was made correctly before operation in 149 of the 155 cases. It was based partly on inferences derived from the nature of the wound. The path of the missile, as determined by an alinement of wounds of entrance and exit, or by the location of the wound of entrance in relation to the roentgenologic position of the retained foreign body (bodies), was the most important diagnostic consideration. A possible injury of the bladder always had to be borne in mind in fractures of the bony pelvis, as well as in occasional instances of abdominal injury following pressure or blast.

Although hematuria and the existence of a urinary fistula pointed to injury of the urinary tract, their absence by no means warranted the conclusion that it had not occurred. Filling the bladder with some solution for diagnostic purposes was not regarded as good practice. If the organ had been punctured, additional contaminated material was likely to escape into the peritoneal cavity, and, more important, extravasation of fluid could occur retroperitoneally and infraperitoneally. Another contraindication to this practice was the fact that the majority of the patients had other abdominal lesions. Since laparotomy was required in all cases, nothing was lost, and the patient's safety was enhanced, by delaying instillation of saline solution through a urethral catheter until the abdomen was opened and conditions could be ascertained and controlled. Not all surgeons employed this method even then.

There were 2 fatalities in the 5 bladder injuries overlooked at operation. Both patients died on the day after operation, of other causes, and the vesical wounds were found at autopsy. The three other patients developed urinary fistulas, through wounds in the thigh, rectum, and abdomen. All were subjected to cystostomy, with satisfactory results.

In one case, a suspected injury to the bladder could not be demonstrated at operation, but an indwelling catheter was nevertheless introduced. When it was removed, on the sixth day, a small foreign body was passed by the urethra. Recovery was thereafter uneventful.

TREATMENT

Since multivisceral wounds were present in most patients with bladder injuries, laparotomy was required, regardless of the vesical wound. It was therefore easy to inspect the intraperitoneal portion of the bladder and carry out such repairs as were necessary. After the peritoneum had been closed and suprapubic cystostomy performed, the extraperitoneal portion of the bladder was inspected, and whatever surgery might be required in that area was carried out.

The bladder injury, as already noted, was not identified at operation in 6 cases. Seven patients died in the course of operation. In 10 other cases there was no record of the type of procedure. In the remaining 132 cases,

repair was done in 116, in 110 of which suprapubic cystostomy was also performed, and 13 patients were submitted to suprapubic cystostomy alone. An indwelling catheter was used in the three other cases. The space of Retzius was drained routinely.

Sulfonamides were occasionally implanted in the peritoneal cavity or in the wound, and penicillin, when it became available, was occasionally used in the same manner. After operation, all patients received a sulfonamide drug by mouth or by vein, penicillin by the intramuscular route, or both agents in combination.

POSTOPERATIVE COMPLICATIONS

In spite of the high frequency of other intra-abdominal injuries, recorded postoperative complications were not numerous in this series of bladder injuries. Atelectasis occurred in 3 cases, and wound infection in 3. Evisceration occurred later in one of the infections. Fecal fistulas developed in 2 cases. Other single recorded complications included pneumonia, cardiac failure, urinary fistula, secondary hemorrhage, pyelitis, epididymitis, and subphrenic abscess. An abscess of unspecified location occurred in one case and pyrexia of undetermined origin in another. There was no instance of infection of the paravesical tissues in any of the surviving patients in the period (1 to 20 days) in which they were followed in forward hospitals, and there was only one instance of retroperitoneal cellulitis among the patients who died.

FACTORS OF MORTALITY

In analyzing the case fatality rate in these 155 wounds of the bladder, it must be borne in mind that 134 of them were multivisceral. Furthermore, in practically all the multiple injuries, the other wounds presented greater technical problems and were of far more serious import than wounds of the bladder. This was particularly true of wounds of the pelvic blood vessels and wounds of the intestinal tract; an intestinal injury was present in every multivisceral wound (table 87).

All 46 deaths (tables 86, 87, and 88) occurred in patients with other intra-abdominal injuries, the case fatality rate rising as the number of other visceral injuries increased. The existence of the bladder wound apparently increased the risk associated with the other injuries. The case fatality rate for 353 univisceral injuries of the ileum and jejunum, for instance, was 13.9 percent (table 50). In the 40 cases in which a bladder injury was associated with the intestinal injury, the rate was 22.5 percent. The case fatality rate for 251 univisceral injuries of the colon was 22.7 percent (table 55). When a bladder injury was associated with the intestinal injury, the rate rose to 42.9 percent. On the other hand, none of the 21 casualties with univisceral lesions of the bladder died, which makes the case fatality rate 34.3 percent (46 deaths) in the 134 multivisceral cases.

TABLE 87.—*Influence of wounds of intestinal tract on case fatality rates in 155 wounds of urinary bladder*

Injuries	Cases	Deaths	Case fatality rate
Total.....	155	46	29.7
Without intestinal injuries.....	21	0	0
With intestinal injuries.....	134	46	34.3
Wounds of—			
extraperitoneal rectum.....	6	1	16.7
intraperitoneal rectum.....	17	3	17.6
small bowel.....	40	9	22.5
colon, exclusive of rectum.....	21	9	42.9
large and small bowel and rectum.....	50	24	48.0

The causes of death (table 88) were those usually responsible for fatalities in abdominal injuries. The shock-mortality relationship followed the expected pattern; namely, the greater the degree of shock when the patients were first seen, the higher the case fatality rate. The rate was 8 percent in patients not in shock, 25 percent in patients in moderate shock, and 63 percent in patients in severe shock.

TABLE 88.—*Primary cause of death in relation to time of death in 42 wounds of urinary bladder*¹

Cause	Day of operation	Postoperative day						Total cases
		1st	2d	3d	4th	5th	6th to 8th, inclusive	
Shock.....	9	2	4					15
Peritonitis.....	1	1	3	1	1			7
Respiratory.....			2	1	1		1	5
Anuria.....			1	1	2			4
Pulmonary embolism.....	1				1	1	1	4
Other ²	4			1	1		1	7
Total.....	15	3	10	4	6	1	3	42

¹ Exclusive of 4 deaths in which the causes are not known and which occurred, respectively, at operation and on the second day, the third day, and between the sixth and eighth days after operation.

² Miscellaneous causes included gas gangrene in 3 cases, a heart lesion and retroperitoneal cellulitis in 1 case each, and (probably) an anesthetic cause in 2 cases.

CHAPTER XXVII

Wounds of the Great Vessels of the Abdomen (75 Casualties)

Hugh F. Swingle, M. D., and Dominic S. Condie, M. D.

There were 75 wounds of one or more of the major vessels of the abdomen included in the 3,154 abdominal injuries treated by the 2d Auxiliary Surgical Group during 1944 and 1945 (table 89).¹ These injuries (table 90) consisted of:

1. Injuries to the major veins, including the vena cava; the common, internal, and external iliac veins; and the portal vein (53 cases).
2. Injuries to major arteries, including the common, internal, and external iliac arteries (13 cases).
3. Injuries to some combination of these arteries and veins (9 cases).

TABLE 89.—*Essential data in 75 wounds of major vessels of abdomen*

Type of injury	Cases	Frequency		Deaths	Case fatality rate
		In 3,154 abdominal injuries	In 75 vascular injuries		
		<i>Percent</i>	<i>Percent</i>		
Vascular only -----	8	0. 25	10. 7	5	62. 5
Vascular and visceral -----	67	2. 13	89. 3	50	74. 6
Total -----	75	2. 38	100. 0	55	73. 3

Of the 75 casualties, 55 (73.3 percent) died, and no soldier with an injury to the abdominal aorta survived long enough to undergo surgery in a field hospital.

INJURIES TO THE MAJOR VEINS

Injuries of the major veins of the abdomen (table 90) occurred alone in 45 cases, in combination with injuries of the blood supply of various viscera in 8 cases, and in combination with injuries of the major arteries of the abdomen in 9 cases.

¹ Injuries to the blood supply of special viscera, such as the colon, spleen, and kidney, are discussed under the heading of the viscus involved and are excluded from this discussion unless they complicated wounds of the major blood vessels of the abdomen. As a matter of convenience, combined injuries of the arteries and veins are discussed under the heading of arterial injuries. Because of the wide distribution of injuries and operations and the small numbers in each category, it is necessary to describe many cases in all categories individually.

TABLE 90.—*Influence of type of injury on case fatality rates of 75 wounds of major vessels of abdomen*

Injury	Cases	Deaths	Case fatality rate
Veins only.....	45	33	73.3
Single vein.....	38	27	71.1
Two or more veins.....	7	6	85.7
Vein and visceral blood supply.....	8	8	100.0
Arteries only.....	13	8	61.5
Artery and vein.....	9	6	66.7
Total.....	75	55	73.3

Vena caval injuries.—The vena cava was injured 33 times (table 91), more frequently than any other single vessel. In the 22 cases in which the injury was univisceral, there were 17 deaths. Nine followed ligation, which was employed in twelve of the univisceral injuries, and four followed suture, which was employed in six cases in the same category. In one fatal case, the vena cava was clamped tangentially, as a temporary measure, and in the three other univisceral fatalities hemorrhage proved uncontrollable.

The were 10 deaths in the 11 injuries associated with injuries of other major abdominal vessels or of the visceral blood supply.

TABLE 91.—*Essential data in 33 injuries of vena cava*

Type of injury and therapy	Cases	Deaths	Case fatality rate
Vena cava:			
Without other injuries.....	22	17	77.3
With other vascular injuries.....	4	3	75.0
With visceral and other vascular injuries.....	7	7	100.0
Total.....	33	27	81.8
Therapy (all vena caval injuries):			
Ligation.....	16	13	81.2
Suture.....	8	5	62.5
Tangential clamping.....	1	1	100.0
Spontaneous thrombosis.....	1	1	100.0
Uncontrollable hemorrhage.....	7	7	100.0

Univisceral injuries of other major veins.—In the 16 univisceral vascular injuries in which veins other than the vena cava were implicated, the distribution of cases, procedures, and deaths was as follows:

Six injuries of the common iliac vein were treated by ligation in five cases and by packing in one case, with four deaths.

Five injuries of the external iliac vein were treated by ligation, with two deaths.

Two injuries of the internal iliac vein were treated by ligation, with one death. Another, similar injury was treated by packing and ended fatally. In the last-mentioned case, the injury was described as involving the "pelvic" vein, but the record left no doubt that the vessel injured was the internal iliac vein.

Two injuries of the portal vein were both fatal. Packing was employed in one case, and in the other hemorrhage was uncontrollable by any measures.

Multiple venous injuries.—In the 7 cases in which 2 or more of the major veins of the abdomen were injured (table 90), the distribution of the cases, procedures, and (6) deaths was as follows:

The inferior vena cava and the common iliac vein were involved in three cases. One patient, treated by suture, survived. One died after venous ligation, and in the third case hemorrhage was uncontrollable.

The inferior vena cava, both common iliac veins, and the right internal iliac vein were injured in one case. Death followed ligation.

The left common iliac vein and the left internal iliac vein were wounded in one case, and the same veins on the right side were wounded in another. Death followed venous ligation in both.

The right internal and external iliac veins were wounded in one case, in which death followed ligation.

Combined injuries of the major abdominal veins and the visceral blood supply.—All eight cases in which venous injuries were combined with injuries of the blood supply of major abdominal viscera ended fatally (table 90):

The inferior vena cava, the hepatic artery, and the portal vein were wounded in one case, in which death was caused by uncontrollable hemorrhage.

The inferior vena cava and the hepatic artery were injured in one case. The artery was ligated, and the vena cava underwent spontaneous thrombosis.

The inferior vena cava and the superior mesenteric artery were injured in one case. The vena cava was ligated and the artery sutured.

The inferior vena cava and the right gastric artery and vein were injured in one case. The gastric artery and vein were ligated, but the patient died of uncontrollable hemorrhage from the vena cava.

The inferior vena cava and the right renal pedicle were injured in three cases. Nephrectomy was done in two cases, once combined with suture, and once with ligation, of the vena cava. In the third case, hemorrhage from both sources proved uncontrollable.

The portal vein and the hepatic artery were injured in one case, in which packing was employed.

INJURIES TO THE MAJOR ARTERIES

Arterial injuries.—In the 13 cases in which major arteries of the abdomen were injured without complicating injuries of other vessels (table 92), the distribution of cases, procedures, and deaths was as follows:

Six wounds of the external iliac artery were treated by suture in one case, with survival, and by ligation in five cases, with four deaths.

Three wounds of the internal iliac artery were treated by ligation, with two deaths.

Four injuries of the common iliac artery were treated by suture in two cases, with survival in both, and by ligation in two cases, with death in both.

Combined arterial and venous injuries.—There were 6 deaths in the 9 combined arterial and venous injuries (table 93). In one instance, a clamp was applied to the internal iliac artery and vein and left in situ because the

TABLE 92.—*Essential data in 13 injuries of major abdominal arteries*

Injuries and therapy	Cases	Deaths	Case fatality rate
Vessel injured:			
External iliac.....	6	4	66.7
Internal iliac.....	3	2	66.7
Common iliac.....	4	2	50.0
Total.....	13	8	61.5
Therapy:			
Ligation.....	10	8	80.0
Suture.....	3	0	0

TABLE 93.—*Essential data in 9 combined injuries of major arteries and veins of abdomen*

Vessel injured and therapy	Cases	Deaths	Case fatality rate
External iliac artery and vein.....	2	1	50.0
Internal iliac artery and vein.....	6	4	66.7
Common iliac artery and vein.....	1	1	100.0
Total.....	9	6	66.7
Therapy:			
Ligation.....	8	5	62.5
Clamp.....	1	1	100.0

patient was moribund; he died before a more definitive procedure could be accomplished. Both the vein and the artery were ligated in the other eight cases. Three patients survived, one with a wound of the external iliac artery and vein and two with wounds of the internal iliac artery and vein.

POSTOPERATIVE VASCULAR INSUFFICIENCY

Postoperative vascular insufficiency occurred in 9 patients in this series who survived injury and operation long enough to present it. The veins were affected in 4 cases, the arteries in 3, and both arteries and veins in 2, as follows:

Two patients with injuries of the inferior vena cava presented swelling of the lower extremity. In one instance, the vein had been ligated. The other patient, who later died of massive pulmonary embolism, had undergone suture of the vein. Two other patients with similar injuries presented distention of the veins of the lower extremities. In one instance, the vena cava had been ligated; in the other, it had been sutured, and it was thought that thrombosis had probably occurred subsequently at the site of injury and repair.

In one injury of the external iliac artery, gangrene followed ligation of the artery and elective ligation of the vein. The leg was demarcating at the midcalf when the patient died on the third day after operation of anuria combined with an overlooked retroperitoneal injury of the cecum. In another injury of the external iliac artery treated by ligation, amputation was necessary at the left midthigh on the seventh day after operation because of gangrene resulting from arterial insufficiency and clostridial myositis.

In one injury of the common iliac artery, the artery was ligated, and elective ligation of the vein was also done. Amputation was later necessary through the thigh on the affected side, and the patient eventually died of clostridial infection in the stump.

In one case in which wounds of the left external and internal iliac veins and the left internal iliac artery were treated by ligation, the affected leg became mottled and cold 12 hours after operation. The patient died 40 hours after operation, in shock from severe peritonitis. Amputation of the extremity would probably have been necessary if he had lived.

In one case in which the left common iliac artery and vein were injured, both vessels were ligated. Gangrene ensued, and amputation of the extremity through the thigh was necessary on the fourth postoperative day.

Conditions in forward hospitals did not permit intensive efforts at combating postoperative vascular insufficiency in the lower extremities. Environmental temperature control was not feasible. No anticoagulant drugs were available. The only practical prophylactic measure was control of the patient's position, and the optimum posture was usually contraindicated by the presence of severe intraperitoneal injuries. A few sympathectomies were done on patients with injuries of the femoral artery, but this procedure was not employed in any intra-abdominal vascular injury.

FACTORS OF MORTALITY

Since the frequency of injury to any abdominal viscus is directly proportional to the space which it occupies (p. 92), it would seem that injury to corresponding major arteries and veins would occur with approximately the same frequency because the vessels are of approximately the same size. In this series of 75 injuries of major abdominal blood vessels, this generalization did not hold. Fifty-three injuries involved one or more veins, while only twenty-two involved either arteries alone or arteries and veins. These figures require interpretation. The considerable discrepancy is probably not a disparity of incidence but rather a disparity in lethality. It arises from the fact that fewer patients with arterial injuries reached field hospitals to undergo treatment. This reasoning is supported by the fact that this series, although it includes 33 lesions of the vena cava, includes no lesion of the abdominal aorta, since no patient with an injury of that vessel survived to undergo surgery. Even when the damage to the veins was severe, many patients were brought to the hospital alive, apparently because a point was reached in the hemorrhagic process at which the intra-abdominal tension was sufficiently high, and the venous pressure had become sufficiently low, to prevent complete exsanguination and death. This physiologic process apparently occurred much less often in arterial injuries, with the result that fewer patients in this category were received in forward hospitals.

The case fatality rate for all arterial injuries was 63.6 percent (14 of 22 cases), as compared to a rate of 75.8 percent (47 of 62 cases) for all injuries of the veins. The lower case fatality rate in arterial injuries must be attributed to unusual circumstances which permitted the patients to reach field hospitals alive. No precise data are available, but it seems reasonable to assume that in these cases the injuries were slight to minimal, the blood loss before operation was not excessive, and bleeding could be controlled promptly after the abdomen was opened.

Only 6 of the 33 patients with injuries of the vena cava (table 91) survived long enough after operation to be evacuated from the field hospital. Three had been treated by suture and three by ligation, the procedure in each instance being performed below the renal veins. No patient survived when the injury was above the renal vessels.

The case fatality rate in injuries of the great vessels apparently rested on much the same basis as injuries of other viscera. Half of the deaths in the 54 fatalities in which the cause of death could be determined resulted from shock and hemorrhage. Twelve were attributed to anuria, four to pulmonary embolism, three each to pneumonia and to pulmonary edema, two each to peritonitis and to clostridial myositis, and one to retroperitoneal suppuration.

One factor of great importance in the outcome was the stage of shock. In very severe shock, the blood pressure and pulse were not usually obtainable, and in several other cases the blood pressure and pulse were not recorded when the patient was first seen in the field hospital. The classification into degrees of shock was therefore made on the clinical findings. The case fatality rate (table 94) was directly proportional to the degree of shock on the patients' admission. The numbers of cases in some categories are too small to be significant statistically, but the results are in full accord with clinical impressions.

TABLE 94.—*Influence of degree of shock on case fatality rates in 69 wounds of major vessels of abdomen*¹

Degree of shock	Cases	Deaths	Case fatality rate
None.....	4	2	50.0
Mild.....	2	1	50.0
Moderate.....	16	10	62.5
Severe.....	8	6	75.0
Very severe.....	39	33	84.6
Total.....	69	52	75.4

¹ In 6 cases, 3 of which were fatal, the degree of shock was not recorded.

The case fatality rate in these 75 vascular injuries also depended upon a number of other considerations, including the presence or absence of associated visceral injuries and the number of viscera involved (table 95). There is one discrepancy—that the rate was higher when no abdominal viscera were involved than when one organ was injured. With this exception, there was a gradual rise in the rate as the number of abdominal organs injured increased. When the multiplicity factor for all abdominal injuries (p. 107) is studied in relation to the multiplicity factor in these 75 cases, it becomes clear that the injury to the great vessels was the most important cause of the consistently high case fatality rate in this group of cases.

Injuries to the great vessels of the abdomen carried the highest case fatality rate of any category of injuries in this series of 3,154 abdominal wounds. No problem so challenged the technical skill of the surgeon as the control of severe intra-abdominal hemorrhage with sufficient rapidity to give the patient a chance of survival.

TABLE 95.—*Influence of multiplicity factor on case fatality rates in 67 wounds of major vessels of abdomen*¹

Organs injured	Cases	Deaths	Case fatality rate
Major vessels only.....	8	5	62.5
Major vessels and 1 viscus.....	22	12	54.5
Major vessels and 2 viscera.....	21	17	81.0
Major vessels and 3 viscera.....	13	11	84.6
Major vessels and 4 viscera.....	1	1	100.0
Major vessels and 5 viscera.....	2	2	100.0
Total.....	67	48	71.6

¹ In 8 cases, 7 of which were fatal, no data are available concerning the number of viscera injured.

CHAPTER XXVIII

Retroperitoneal Hematoma (207 Casualties)

Hugh F. Swingle, M. D., and Dominic S. Condie, M. D.

It is known that retroperitoneal hematoma, in the sense of an extravasation of blood, either circumscribed or diffuse, into the retroperitoneal tissues was frequently encountered in the 3,154 abdominal injuries observed by the 2d Auxiliary Surgical Group in 1944 and 1945. The exact frequency, however, is unknown because the data were recorded in only 207 cases, in 59 of which a hematoma was the only lesion present.

There are several reasons why this number of cases of retroperitoneal hematoma cannot be accepted as correct:

1. It can be assumed that a missile which entered the retroperitoneal space almost inevitably produced a hematoma of some sort.
2. Blunt, nonpenetrating injuries frequently had the same effect.
3. The 207 recorded cases are far fewer than the 427 renal wounds in this series of abdominal injuries.
4. A retroperitoneal hematoma was specifically mentioned in only 33 of the 75 wounds of the major abdominal blood vessels, though it is inconceivable that it was not present in every such injury. As a matter of fact, after only a brief experience, the surgeons of the 2d Auxiliary Surgical Group came to regard the presence of a hematoma as likely in any wound of the retroperitoneal space and usually did not record it unless it was the only lesion present or it was of significant severity. In other words, whatever the actual statistics may indicate, this was a lesion of considerable frequency in this series of abdominal wounds.

CLINICAL CONSIDERATIONS

It was usually impossible to make an accurate diagnosis of retroperitoneal hematoma by clinical means alone. It was equally impossible, prior to operation, to differentiate between it and intra-abdominal visceral injury. The signs and symptoms of both conditions were usually identical, and in this series both lesions frequently occurred in the same patient.

There was no instance in this series of the so-called retroperitoneal syndrome observed by Jolly¹ in the Spanish Civil War and explained by the retroperitoneal infiltration of blood about the celiac plexus. This syndrome consists of a state of shock, with generalized pallor and sweating; a rapid, thready pulse, often becoming imperceptible; a complete absence of any symptoms or signs referable to the abdomen; and a semierrection of the penis. The

¹ Jolly, Douglas W.: *Field Surgery in Total War*. New York: Paul B. Hoeber, Inc., 1941.

latter sign was not constantly present in Jolly's cases, but when it appeared it was of grave prognostic import and usually persisted until death. In this series of cases, on the contrary, the signs and symptoms of retroperitoneal hematoma were seldom distinguishable from those associated with perforation of a hollow viscus. Priapism was usually associated with injury to the spinal cord. In the occasional case in which it was present with retroperitoneal hematoma, the prognosis was not grave.

TREATMENT

Many of the retroperitoneal extravasations of blood observed in this series had little or no pathologic significance and required no special treatment. On the other hand, the feeling that most of them could be regarded as of no importance led, in the occasional case, to the overlooking of a serious injury and even to a fatality.

From the standpoint of treatment, the 207 completely recorded retroperitoneal hematomas in this series can be divided into three groups:

One hundred and eleven patients, of whom nineteen died, had no specific treatment related to the hematoma, presumably because it was thought to be too insignificant to warrant any.

Sixty-three patients, of whom twenty-two died, for the most part were treated by drainage, with or without evacuation of the clot. Packing was occasionally employed, or, when it was possible, a bleeding vessel was ligated.

Thirty-three patients, of whom twenty-two died, had associated injuries of the great vessels of the abdomen. Treatment in these cases consisted of evacuation of the blood clot and control of the bleeding vessel by ligation, suture, or clamping.

The most important implication of a retroperitoneal hematoma, aside from the fact that the clinical signs could not be distinguished from signs of visceral perforation, was that it might obscure injury to the vital retroperitoneal structures. That happened a number of times in this series. Lesions overlooked included a duodenal perforation, 2 ureteral injuries, 4 retroperitoneal injuries of the colon, and 6 injuries of the bladder. There were only 5 survivals in these 12 cases, 1 in the 4 injuries of the colon and 4 in the 6 injuries of the bladder. It is easy to understand how these errors occurred. While small hematomas required no treatment, large hematomas, and those in which there was evidence of continued bleeding, urgently required exploration and control of the bleeding vessels. Under these conditions, it was difficult to identify a coexisting lesion, such as a perforation of the colon on its retroperitoneal aspect.

FACTORS OF MORTALITY

There were 4 deaths (6.8 percent) among the 59 patients who had no injuries other than the retroperitoneal hematoma. The case fatality rate is of the same order as the rate (4.9 percent) in abdominal injuries without visceral wounds.

The 19 fatalities in the 111 cases in which there was no specific treatment of the retroperitoneal hematoma were all attributable to concurrent visceral injuries. Similarly, the 22 deaths which occurred in the 33 hematomas associated with injuries of the great vessels were directly related to the vascular injuries. In both groups, the fatalities were not related to the retroperitoneal bleeding.

Of the 22 deaths which occurred in the 63 retroperitoneal hematomas treated directly, 11 were attributable to the retroperitoneal lesion itself. Five patients died of shock and hemorrhage as a result of severe retroperitoneal bleeding, and three died of anuria following shock of the same origin. The three other patients died of retroperitoneal cellulitis, in one instance associated with pulmonary embolism.

The low case fatality rate in the group of cases in which there was no lesion other than the retroperitoneal hematoma is apparently related to the relatively low incidence of shock. In 18 of the 59 cases, 1 of them a fatality, there was no record on this point. Twenty-five of the remaining 41 patients, 1 of whom died, were stated not to be in shock. Sixteen presented some degree of shock. There were no deaths in the 7 patients in mild shock, 1 death in the 6 in moderate shock, and 1 in the 3 in severe shock. In general, therefore, there was less shock, and less fatal shock, in this group than was usually encountered in a group of similar size with injury limited to a single viscus.

As their experience with retroperitoneal hematoma increased, the surgeons of the 2d Auxiliary Surgical Group formulated a routine plan of management for this condition:

1. After the evacuation of a large hematoma in the retroperitoneal space and control of the bleeding responsible for it, the surrounding structures were carefully explored. They were similarly explored in the presence of any hematoma, regardless of its size, if its anatomic location was such as to suggest possible injury to the ureter, the bladder, the duodenum, or the posterior aspect of the colon.

2. Adequate extraperitoneal drainage was provided for retroperitoneal hematomas associated with injury to any portion of the urinary tract, the colon, or the pancreas. If a debrided missile wound of entry or exit was not suitable for this purpose, drainage was instituted through a surgical incision in the flank or through a posterior incision.

3. Evacuation of the clot and ligation of the bleeding vessel or vessels were usually all that was necessary in large hematomas caused by vascular injuries.

4. Any opening in the posterior peritoneum, whether made by the missile or created during the operative procedure, was carefully retroperitonealized, to eliminate communication between the peritoneal cavity and the retroperitoneal space.

CHAPTER XXIX

Special Types of Abdominal Injury

Gordon F. Madding, M. D., and Knowles B. Lawrence, M. D.

VISCERAL INJURIES WITHOUT PENETRATION OF THE PERITONEAL LAYER OF THE ABDOMINAL WALL

In 12 of the 3,154 abdominal injuries observed by the 2d Auxiliary Surgical Group during 1944 and 1945, injuries of abdominal viscera occurred without penetration of the abdominal wall by the wounding missile (table 96).

In 10 of the 12 cases the missile, while it caused a through-and-through wound of the abdominal parietes, did not injure the peritoneum. In the 2 other cases, the foreign body was retained within the abdominal wall. The velocities of the missiles causing the through-and-through wounds were apparently greater than those of the missiles retained within the abdominal wall. It may be assumed that the additional imparted energy produced an explosive effect in the abdominal wall, and that this effect was imparted, in turn, to the intra-abdominal structures.

The fact that viscera containing gas and liquid (that is, hollow viscera) were injured in 9 of the 12 cases suggests that this type of viscus may be peculiarly prone to injury from indirect trauma because of the transmission of the force of the missile by the visceral contents. The fact that in one case (table 96, case 3) the cecum and ascending colon were split open along the anterior longitudinal band seems to support this theory.

In the single fatal case in this group (table 96, case 8) the patient sustained a severe wound of the left chest. The missile lacerated the pleural surface of the left dome of the diaphragm, with apparent indentation of the stomach wall and production of a subserosal hematoma in that area. Pulmonary damage was extensive, and the intra-abdominal injury seems to have played no significant part in the fatality, which was the result of shock and pulmonary edema.

The experience of the group surgeons with injuries of the abdominal wall which did not involve the peritoneal layer clearly indicates that it would have been an error to assume that there was no intra-abdominal visceral injury merely because the missile did not enter the peritoneal cavity. Whenever there was clinical evidence of intraperitoneal involvement, exploration was regarded as mandatory. The visceral injuries thus found in this series are proof of the wisdom of that policy.

TABLE 96.—*Essential data in 12 injuries of intraperitoneal viscera without penetration of peritoneal layer of abdominal wall*

Case	Wounding agent	Type of wound	Location of wound	Organ injured	Lesion	Treatment	Comment
1	Not recorded	Penetrating ¹	Left lower quadrant	Descending colon	Incomplete laceration	Suture	Patient also had compound fracture of femur.
2	do	Perforating ²	Right flank	Liver	Minor laceration	Drainage	
3	Shell fragment	do	Right upper quadrant	Cecum and ascending colon	Complete laceration	Exteriorization	
4	do	do	do	Liver	Stellate tear, right lobe	Drainage	Died of shock and pulmonary edema, from extensive lung injury.
5	do	do	Left abdomen	Spleen	Splenic laceration	Splenectomy	
6	do	do	do	Ileum	Contusion	Laparotomy	
7	do	Penetrating	Right flank	Ascending colon	Small anterior perforation	Suture	
8	Not recorded	Perforating	Left chest	Stomach	Hematoma of wall	Thoracotomy; transdiaphragmatic abdominal exploration	Died of shock and pulmonary edema, from extensive lung injury.
9	Shell fragment	do	Right abdomen	Cecum	Contusion	Laparotomy	
10	do	do	do	Ascending colon	Perforation and contusions	Exteriorization	
11	Not recorded	do	Posterolateral left chest	Splenic flexure of colon; jejunum	Perforation, colon; contusions, jejunum	Exteriorization of colon	
12	Shell fragment	do	Left chest and left abdominal wall	Left lobe of liver, transverse colon, jejunum	Lacerations	Drainage of liver; exteriorization of colon; suture of jejunum	

¹ Penetrating: Missile retained in abdominal wall; peritoneum intact.² Perforating: Through-and-through wound of abdominal parietes; peritoneum intact.

VISCERAL INJURIES CAUSED BY BLUNT TRAUMA AND BLAST

Perforation or rupture of an intra-abdominal viscus, which is always a possibility in any instance of blunt trauma or blast, occurred in 14 of the 3,154 abdominal injuries in this series (0.44 percent) in the absence of peritoneal penetration (table 97). These cases are exclusive of injuries to the bladder, urethra, and other urogenital structures associated with fractures of the pelvis. The small intestine, the spleen, the colon, the mesentery, and the kidney were most frequently injured, alone or in combination.

Nine of the fourteen injuries resulted from vehicular accidents and three from blast from a nearby explosion of an artillery shell. Occasionally a subcutaneous hemorrhage indicated the area of greatest trauma, but in none of these injuries was there a skin wound. The diagnosis of possible intra-abdominal injury was made in 13 of the 14 cases by the history of injury and the physical findings. Tenderness was usually present, and peristalsis was constantly absent. In the remaining case (table 97, case 14) an extensive thoracic injury overshadowed the abdominal injury, which was not suspected until autopsy.

The case fatality rate in this group (2 deaths in 14 cases) is considerably lower than the rates of 44 and 55 percent reported in the literature for this type of injury. The good results are attributable to early and vigorous therapy for shock, followed by prompt surgical intervention. The series may be small, but in the majority of cases the lesions were such that death would undoubtedly have occurred in the absence of surgical intervention.

PENETRATING (PERFORATING) WOUNDS OF THE ABDOMINAL WALL WITHOUT VISCERAL INJURIES

The peritoneal cavity was penetrated in 41 of the 3,154 abdominal wounds in this series (1.3 percent) without significant damage to any of the intraperitoneal viscera.¹ The wounds were perforating in 11 of the 40 recorded cases and penetrating in the other 29. The wounding agent was listed as a high-explosive shell fragment in 33 cases and as gunshot in the other 8.

In 24 of the 41 cases, the wounds were thoracoabdominal. This proportion (58.5 percent) differs materially from the 26.2 percent of thoracoabdominal wounds in the entire series of 3,154 abdominal injuries, though the figures are too small to be of real significance. The right diaphragm was wounded 13 times and the left 11 times. In 23 of the 24 cases in this group, the missile entered the peritoneal cavity from the thorax. In 7 cases, there was a double perforation of the diaphragm, the missile either lodging in the lung or passing out through the chest wall. In 2 of the 11 single perforating wounds, the injury was produced by sharp rib fragments. In the 5 other cases in which

¹ Three similar cases in which only the omentum was injured are not included in these 41 cases. In 2 of the 3, small rents in the omentum were repaired by suture. In the third case, a segment of omentum had herniated through a perforation in the diaphragm and become gangrenous. Resection was followed by an uneventful recovery.

TABLE 97.—*Essential data in 14 intra-abdominal injuries caused by blunt trauma and external blast*

Case	Wounding agent	Type of injury	Location of wound	Organ injured	Lesion	Treatment	Postoperative course
1	Jeep	Contusion	Left flank	Ileum, descending colon.	Transsection ileum, laceration colon.	Resection ileum, exteriorization colon.	Uneventful.
2	do	do	Abdominal wall	Ileum	Lacerations	Suture	Do.
3	Jeep	do	Left upper quadrant	Spleen	Pedicle torn	Splenectomy	Pneumonia.
4	do	do	Left flank	Kidney, mesentery	Tear splenic pedicle, tear mesentery.	Nephrectomy, suture mesentery.	Uneventful.
5	Shell explosion	Blast, contusion	Abdominal wall	Spleen	Fracture	Splenectomy	Wound dehiscence seventh postoperative day, secondary closure.
6	Half track	Crushing	do	Descending colon	Serosal tears	Suture	Uneventful.
7	Command car	do	do	Jejunum	Transsection	do	Do.
8	Jeep	Contusion	Right groin	Ileum	Laceration	do	Do.
9	Wagon	Crushing	Abdominal wall	do	do	do	Do.
10	Automobile	Blunt	Abdomen	Jejunum, mesentery, transverse colon.	Transsection jejunum, tear mesentery, tear serosa colon.	Resection jejunum, suture mesentery, colon.	Death 13th postoperative day, peritonitis, pneumonia.
11	Shell explosion	Blast	do	Spleen	Fracture	Splenectomy	Uneventful.
12	Fall 42 feet	Blunt	Left flank	Spleen, left kidney	Fracture spleen, tear renal pedicle.	Splenectomy, nephrectomy.	Do.
13	Bailey bridge injury	do	Left hypochondrium	Descending colon	Division and retraction taenia coli.	Suture, exteriorization.	Do.
14	Shell explosion	Perforating wound chest wall, blast injury abdomen.	Left chest, left abdomen, left arm.	Lung, stomach, small bowel, colon.	Blast injury lung, subserosal gastric hemorrhage, tears and hemorrhage intestinal mucosa.	Debridement chest wall.	Death 17th postoperative day from acute circulatory collapse and intestinal obstruction. Abdominal lesions not diagnosed until autopsy.

the missile entered the abdomen from the thorax, it lodged in the diaphragm and caused only a small opening in the peritoneum.

In none of the 17 abdominal wounds had the missile passed freely across or through the general peritoneal cavity in a major diameter. In every instance, the peritoneal wound had been caused by missiles which had either perforated the cavity across small angles, lacerated the peritoneum in burrowing through extraperitoneal tissues, or so exhausted their momentum as to fall harmlessly into the peritoneal cavity.

Hemoperitoneum in varying degrees, all from extraperitoneal sources, was present in most of the 41 cases. It was this blood, sometimes more than a liter, which produced the clinical symptoms and signs of an intraperitoneal lesion.

The surgical approach in each instance was determined by the type of wound. In 20 of the 24 thoracoabdominal wounds, exploration was carried out through the chest and diaphragm. In two other cases, it was carried out through separate incisions in the chest and abdomen. The remaining operations were performed through abdominal incisions. The wound of the diaphragm was sutured in all thoracoabdominal wounds.

There were 2 deaths in the 41 cases. One patient, who had sustained an evisceration of 18 inches of ileum through a wound of the abdominal wall, died unexpectedly, 3 days after operation, of massive pulmonary embolism, the origin of which was not stated. In the other fatal case, a severe retroperitoneal injury with severance of the left common iliac vessels, death occurred 10 days after operation, from peritonitis, retroperitoneal cellulitis, and pneumonia.

The most important observation made in this group of cases is that in not a single instance did a missile pass harmlessly across the general peritoneal cavity in a major diameter. Since the whole series represents a very large number of cases (3,154) and since the policy was to explore every injury in which there was evidence of or suspicion of peritoneal penetration, it would seem that perforating wounds of the peritoneal cavity in which there is no injury of the intraperitoneal structures must be extremely uncommon. It is true that because of the tendency of certain wounds of the gastrointestinal tract to seal over, clinical recovery may occasionally ensue in such cases, without surgery and therefore without diagnosis, but because of the excellent surgical service and facilities provided in forward hospitals in World War II, the risks involved in the nonsurgical management of this type of wound would not have been justified.

Part III
COLOSTOMY

CHAPTER XXX

The Management of Colostomies

David Henry Poer, M. D.

HISTORICAL NOTE

Although colostomy was a well-established procedure in civilian surgical practice at the beginning of World War I, military surgeons of all armies were slow to employ it.¹ The chief reason was that during the early months of this war, as in all previous wars, nonintervention was the general rule in abdominal injuries. This was partly because of the poor results which had attended previous efforts at intervention and partly because the majority of surgeons did not regard major surgery as practical near the front. Since abdominal surgery, to have any hope of success, had to be performed within a reasonably short time after injury, this pessimistic point of view automatically excluded the surgical management of these injuries.

Many surgeons, even in 1914, did not accept these premises, and as the war progressed the concept became more and more general that recovery could be expected in abdominal injuries if operation was performed. As mobile hospital facilities, equipped and staffed for surgery, were set up near the front, the practice of prompt surgery for these injuries became increasingly frequent, and in 1917 and 1918 operation became the general rule in both the British and the American Armies.

Colostomy, however, was never adopted as a routine technique in wounds of the large bowel. Instead, it was usually reserved for the most seriously wounded patients, with extensive wounds of the colon. These casualties formed a distinctly unfavorable group, and the high case fatality rate which attended the use of colostomy was no more than might have been expected.

Wallace, who wrote the section on abdominal injuries for the official British medical history of World War I,² did not mention colostomy as a method of dealing with wounds of the cecum. He considered suture preferable whenever it was feasible in wounds of the transverse and vertical colons, and he also stressed the importance of drainage. Colostomy, he indicated, was an undesirable alternative, which was most likely to be necessary in injuries of the splenic flexure. Its widest application, in his opinion, was in left-sided wounds of the

¹ (1) History of the Great War Based on Official Documents. Medical Services Surgery of the War. London: His Majesty's Stationery Office, 1922, vol. I, pp. 476-579. (2) The Medical Department of the United States Army in the World War. Washington: U. S. Government Printing Office, 1927, vol. XI, pt. 1, pp. 443-490.

² Wallace, C. S.: Wounds of the Abdominal Viscera. In History of the Great War Based on Official Documents. See footnote 1 (1).

loin, in which sepsis tends to develop late, and in rectal injuries. Colostomy was employed only 53 times in the 155 injuries of the large bowel upon which Wallace based his discussion. It was, however, widely used in base hospitals in the management of fecal fistulas which developed after failure of suture repair.

The results which Wallace cited explain why colostomy was not a popular procedure among British surgeons in World War I. The case fatality rate in wounds of the colon, he pointed out, was higher when it was employed; 73.5 percent as compared with just over 50 percent in cases managed by suture. These figures, Wallace added, must not be taken to indicate that colostomy is a necessarily dangerous procedure. They merely indicated that fatal sepsis was likely to occur when colostomy was employed, because infection was already present when the operation was performed.

Lee, who wrote the section on abdominal injuries in the official United States medical history of World War I,³ set down the following general principles for the management of wounds of the colon:

1. Suture should be performed whenever it is possible, in order to secure a satisfactory closure.
2. Colostomy should always be employed in preference to resection.
3. Colostomy is preferable in all injuries with large, ragged openings, particularly injuries of the cecum, descending colon, and sigmoid.
4. Drainage should be used routinely in proved or suspected retroperitoneal injuries. It should always be used when there is any doubt of the integrity of the suture line.
5. Colostomy may be required in extensive lacerations of the lower rectum and in rectal injuries deep in the pelvis, in which suture is not possible. According to Lee, the results of suture repair were better than those of colostomy, in which the case fatality rate was 70 percent.

Jolly's⁴ extensive personal experience as a field surgeon in the Spanish Civil War included 970 abdominal injuries. In his book on field surgery in total war⁵ he described invaginating suture and resection as alternative methods of treatment in wounds of the colon. He emphasized the importance of drainage but did not mention colostomy.

COLOSTOMY IN OVERSEAS HOSPITALS

The attitude of surgeons toward colostomy in World War II is an interesting contrast to the opinion held of it early in World War I and in the Spanish Civil War, which ended only about 3 years before the United States entered World War II. Its lifesaving properties were recognized almost at once, and, together with exteriorization of the damaged segment of bowel, it became the routine method of management for injuries of the large bowel. This policy,

³ Lee, Burton, J.: Wounds of the Abdomen. In the Medical Department of the United States Army in the World War. See footnote 1 (2), p. 337.

⁴ Jolly, Douglas W.: Field Surgery in Total War. New York: Paul B. Hoeber, Inc., 1941.

⁵ Ibid.

which saved many thousands of lives, can fairly be regarded as one of the most important advances ever made in the treatment of battle-incurred injuries of the colon.

Colostomy, with and without exteriorization of the damaged bowel, was first used by British surgeons during the air bombardment of London in 1940 and 1941, at the repeated suggestion of Ogilvie.⁶

The new policy was apparently dictated by two considerations. The first was the success of this method of management of intestinal tumors in civilian practice. The affected segment of bowel was brought outside the abdomen at the first operation and resected later at a second-stage operation. The second consideration was the prohibitively high case fatality rate associated with immediate repair of injuries of the colon and replacement of the bowel into the abdominal cavity. As Ogilvie remarked later, in a report of the British experience with abdominal injuries in the Western Desert,⁷ it would be rash to claim that any of the patients who died after colostomy could have

⁶ In a personal communication to the author of this chapter, dated 24 May 1955, Sir Heneage Ogilvie pointed out that much of this teaching was informal. He had first publicly advocated the use of colostomy for wounds of the large bowel at a lecture given at the Postgraduate Hospital in Hammersmith, England, late in 1939. This lecture was one of a series prepared for the emergency and dealing with the surgical treatment of wounds of warfare. How to manage wounds of the colon was vigorously discussed by the numerous surgeons present, and at this meeting, as well as at later meetings, a certain amount of opposition to the policy of colostomy was expressed.

A lecture given by Sir Heneage in Kenya, when he was consulting surgeon to the East African Force which was conducting the attack on Abyssinia from the south, was reproduced in the June 1941 issue of the East African Medical Journal. The substance of the recommendations concerning the management of wounds of the colon was as follows:

"Holes in the free portions of the colon may be closed by a purse-string suture if the bowel wall round them is perfectly healthy, but in most cases a local repair is unsafe and resection is wise. A free mobilisation is often required before the resected ends can be brought together without tension. Nearly all writers on military surgery advise end-to-end suture after resection, with or without caecostomy, but this advice is unsound in the light of modern teaching and practice, and the high mortality in colon wounds in all published statistics suggests that it is not good treatment. After mobilisation sufficient to allow the colon above and below the injury to be approximated without tension, the injured segment should be removed and the cut ends above and below it, closed with crushing clamps, should be brought to the surface at one end of the incision or wound. The clamps are removed after 24 hours, and the continuity of the bowel is restored later by crushing the spur between the openings.

"There has been a marked tendency in recent years to look on the large intestine with increasing respect or even fear. Its walls are thin, their blood-supply is poor, and the peritoneal coat is interrupted by a broad mesentery and distorted by fat blisters, the contents are highly infective and mechanically traumatic, its luminal pressure alters with explosive suddenness. No sutures can be placed accurately in its wall, and what are thought to be leakers often pass through all coats and carry infection. All surgeons have experienced trouble with leakage and sepsis at the suture line after resection and many feel today that no stitch should ever be put through a colon that is not both empty and sterile. A colostomy or a resected loop should not be stitched to the skin, but the skin openings should be made to fit the colostomy; a segment of bowel should not be excised and the ends sutured unless the contents have been diverted above by an excluding colostomy for at least 2 weeks. Devine has shown the way to success in cancer of the colon by his operation of exclusion and Lahey has made resection of the colon for ulcerative colitis and of the rectum for cancer safe by stage operations in which the bowel is brought to the surface. In war injuries, the way to safety is the same, for caecostomy provides only partial relief of tension at the injured site and proximal colostomy is no better unless it is done some weeks before."

The same advice was repeated in various memorandums circulated in the British East African Force in 1941 and in the British Middle East Force in 1942 and 1943, as well as in a field manual published for the use of British troops during the invasion of the Continent in June 1944. Meantime, Ogilvie had published his comprehensive report *Abdominal Wounds in the Western Desert* (March 1944, see footnote 7).

The personal communication from Sir Heneage Ogilvie from which the information in this footnote has been taken concludes with the following paragraph:

"Under the influence of these antiseptics [the effective intestinal antiseptics which were later developed], with improved surgical conditions and with the development of skilled surgery in the forward units, the policy was somewhat modified in that closure of small perforations in the proximal colon was countenanced if the surgeon was a man of considerable experience and if the case could be retained for the first 10 days for observation. However, as far as I know, up to the end of the war it was considered that exteriorisation of all colon wounds was the safest policy and the one to be recommended to all surgeons undertaking the abdominal surgery of warfare for the first time."

⁷ Ogilvie, W. H.: *Abdominal Wounds in the Western Desert*. Surg., Gynec. & Obst. 78: 225-238, March 1944.

been saved by suture alone, but there was no doubt that certain of the deaths which occurred after suture of the injured bowel could have been avoided by colostomy. In his opinion, the exteriorization of the damaged colon was one of seven decisive points in the management of abdominal injuries. By this time (1943) the British experience had been sufficiently large for him to be able to analyze the conditions which made closure of a colostomy stoma difficult and to suggest improved techniques.

The American experience.—Colostomy was extensively employed in injuries of the colon during the North African campaign in 1942–43, at first, it would seem, without knowledge of the earlier British experience. Circular Letter No. 20, 22 June 1943, Office of the Surgeon, North African Theater of Operations, consisted chiefly of comments from hospitals of the Communications Zone, North African Theater of Operations, United States Army, on the management of battle casualties in forward areas during the fighting in Tunisia. One of the criticisms had to do with failure to perform immediate colostomy in retroperitoneal injuries of the rectum.

Colostomy became official practice for injuries of the large bowel when Circular Letter No. 178, dated 23 October 1943, was issued from the Office of The Surgeon General of the Army. The instructions were that—

* * * in large bowel injuries, the damaged segment will be exteriorized by drawing it out through a separate incision, preferably in the flank. In order to facilitate subsequent closure the two limbs of the loop should be approximated by suture for a distance of about 2½ inches and then returned to the abdomen, leaving the apex exteriorized with a short length of rubber tubing or other suitable material beneath it. If the segment cannot be mobilized, the injury should be repaired and a proximal colostomy done.

Thereafter in World War II, surgery of the colon in the United States Army was based on three general principles: (1) Exteriorization of the wounded portions of the bowel (fig. 31), to avoid intraperitoneal contamination; (2) complete diversion of the fecal stream away from distal wounds of the colon and rectum; and (3) colostomy to effect incomplete diversion of the fecal stream for purposes of gaseous decompression as well as possible future complete diversion.

Soldiers with wounds of the colon were for the most part treated in field hospitals, located near division clearing stations. They were brought to them and were prepared for surgery by resuscitative measures within a remarkably short time. Figures of the 2d Auxiliary Surgical Group (p. 256) show that the average timelag between wounding and operation in 1,222 wounds of the colon and rectum was 10.9 hours. The speed with which treatment was instituted in itself saved many lives. Strict adherence to the policy of exteriorization of the bowel and colostomy shortened the time necessary to care for wounds of the colon and saved additional lives by making earlier treatment possible for other wounded men.

During the early American participation in the war, revision of the colostomy stoma was undertaken, when it was indicated, in fixed hospitals overseas, after which the casualties were returned to the Zone of Interior for reconstructive surgery and closure of the opening in the bowel. As experience



FIGURE 31.—Loop of damaged sigmoid exteriorized through separate inguinal incision 12 days after wounding. When the edema now present subsides, a satisfactorily functioning colostomy will remain until it is closed.

increased and additional trained surgeons were sent overseas, closure of the colostomy was frequently effected in numbered general hospitals in the communications zone. This was a common British practice. Ogilvie related that men who had been wounded in the abdomen at El Alamein marched with the British Eighth Army into Tunis. Similarly, many United States soldiers who had sustained wounds of the colon and had been treated by colostomy were able to return to active military duty in the theaters in which they had been wounded.

For many reasons, however, it was more expedient to close most colostomies in general hospitals in the Zone of Interior, and the greater part of the data upon which this chapter is based concern that experience.

COLOSTOMY IN ZONE OF INTERIOR HOSPITALS

Basic Data

During the winter of 1945-46, questionnaires dealing with various aspects of colostomy were sent to all general hospitals in the United States. Although

many hospitals had been closed by this time and their records had been forwarded to a general collection center, the replies received furnished information on 2,378 soldiers with wounds of the colon who had been treated by colostomy in forward hospitals overseas. As might have been expected, since a large majority of these patients had already undergone disposition proceedings, numerous details were missing on many of the records.

For convenience, and because of the deficits in the data just mentioned, these 2,378 cases are discussed in the following groupings:

1. Two thousand one hundred and two cases in which closure had been done in Zone of Interior hospitals and on which information had been secured when the final analysis of cases was begun.
2. Four hundred and sixty-four cases included in the two thousand one hundred and two cases just mentioned and reported from ten general hospitals in the Fifth and Sixth Service Commands and from McCloskey General Hospital in the Eighth Service Command (series A). These data were unusually complete and, for that reason, are frequently discussed separately.
3. One hundred and eighty cases in which the colostomy had been closed in eight overseas hospitals (series B).
4. Ninety-six cases from Rhodes General Hospital in the Second Service Command (series C). These data were received after the rest of the material had been analyzed but are discussed separately at appropriate places.

Techniques of Colostomy

As might be expected, when so many surgeons had operated on so many patients and under such widely different circumstances, the 2,378 colostomies which make up this composite series represented every known technique. In approximately 300 cases, no details were stated. Loop colostomy with a single opening was performed in 40 percent of the remaining cases, the Paul-Mikulicz colostomy with spur in 30 percent, the Devine technique or some modification thereof and mucous fistulas with single or multiple openings in 10 percent each, and the tube or tangential colostomy and the loop colostomy with double openings in 5 percent each. The colostomy was located on the left side in 50 percent of the stated cases, in the transverse colon in 30 percent, and on the right side in 17 percent. The remaining operations were in the sacral region.

The location of the wound and of the colostomy was not stated in a large proportion of the records. In series A, the wound was on the left side in about a third of the 416 stated cases, and the colostomy was on this side in about 58 percent of the 338 stated cases.

<i>Location of wound</i>		<i>Cases</i>
Right colon:		
Cecum.....	44	
Ascending colon.....	35	
Hepatic flexure.....	13	
	92	92
Transverse colon.....		72
Left colon:		
Splenic flexure.....	20	
Descending colon.....	42	
Sigmoid.....	78	
	140	140
Rectum.....		112
Total.....		416

<i>Location of colostomy</i>		<i>Cases</i>
Right colon:		
Ileum.....	¹ (21)	
Cecum.....	27	
Ascending colon.....	26	
Hepatic flexure.....	12	
	65	65
Transverse colon.....		75
Left colon:		
Splenic flexure.....	13	
Descending colon.....	24	
Sigmoid.....	158	
	195	195
Sacral.....		3
Total.....		338

¹ Not included in figures for the right colon. As is noted in the text, the ileum is not a desirable location for enterostomy in wounds of the colon, but it was used in some instances because of errors in judgment and in others because of technical errors at operation.

Preclosure Problems in Zone of Interior Hospitals

The eventual medical policy in the management of wounds of the colon was, as already stated, to close the stoma in almost all instances in Zone of Interior hospitals. Closure, however, involved considerably more than the actual operative act. It required very careful preoperative preparation, the routine of which was based upon the problems presented in the special case. Among these problems the following were the most important:

Associated wounds.—Well over half of the patients received in Zone of Interior hospitals with unclosed colostomies had other major injuries, which in many instances were multiple (see following tabulation of associated visceral injuries in 179 patients in series A). Wounds of the small intestine were particularly frequent; series A, in which they made up considerably over half of all associated wounds, is typical. Fractures of the long bones represented as much as 40 percent of associated injuries in many hospitals. A few patients in each hospital were paraplegic.

<i>Organ</i>	<i>Cases</i>
Esophagus.....	1
Stomach.....	31
Small intestine:	
Duodenum.....	6
Jejunum.....	80
Ileum.....	126
Not stated.....	29
	<hr/> 241
Appendix.....	241
Gallbladder.....	1
Liver.....	8
Spleen.....	32
Diaphragm.....	16
Urinary tract.....	17
Spinal cord.....	64
	<hr/> 9
Total.....	<hr/> 420

The majority of the associated injuries were well on the way to healing when the patients reached the United States, but the associated injuries sometimes required attention more urgently than did the colostomy. If fractures, for instance, had to be treated by balanced suspension skeletal traction, closure of the colostomy stoma was not feasible immediately; it was desirable that the patient be ambulatory before abdominal surgery was undertaken. Nerve suture and plastic surgery, on the other hand, were usually postponed until after the colostomy had been closed.

Organic disease was not usual in young, sturdy soldiers, but three patients at McCloskey General Hospital had pulmonary tuberculosis. There were also occasional instances of this and other diseases at other hospitals.

Nutritional status.—Almost all of the patients who arrived in the Zone of Interior with unclosed colostomies had lost weight (fig. 32). At one typical hospital, the weight loss ranged from 10 to 80 pounds and averaged 36 pounds. In numerous instances, the patients were at least partly responsible for their own poor nutritional status. They deliberately restricted their food intake in order to decrease the number of daily dressings required. Hypoproteinemia was found in about 10 percent of the serum-protein determinations, but other-



FIGURE 32.—Right-sided colostomy. The cecum and ascending colon were resected at the first operation after wounding, and the ends were implanted into the incisions. After resection, the ends were brought out, and an ileostomy and colostomy were created. Note the extreme emaciation which accompanies right-sided colostomy. This patient also had a fecal fistula in the buttocks. After a long period of careful preparation, intestinal continuity was restored by ileotransverse colostomy. Full recovery followed.

wise there was little evidence of serious alteration in the basic constituents of the blood except in patients with wounds on the right side, complicated by drainage from the small intestine.

Complications related to the colostomy.—The series A statistics may be taken as typical of the collected series in respect to complications related to the colostomy. In 275 of the 464 cases, herniation of various degrees had occurred; in some instances the bowel actually protruded through itself (that is, through the colostomy stoma). Fecal fistulas were present in 70 patients, wound infection of some degree in 38, obstruction of some degree in 34, fistulas into the buttocks in 31, osteomyelitis in 25, wound dehiscence in 10, and peritonitis in 7. Complications of wounding unrelated to the colostomy included urinary fistula in 7 cases, empyema in 2, thrombophlebitis in 2, and a fistula of the biliary tract in 1.

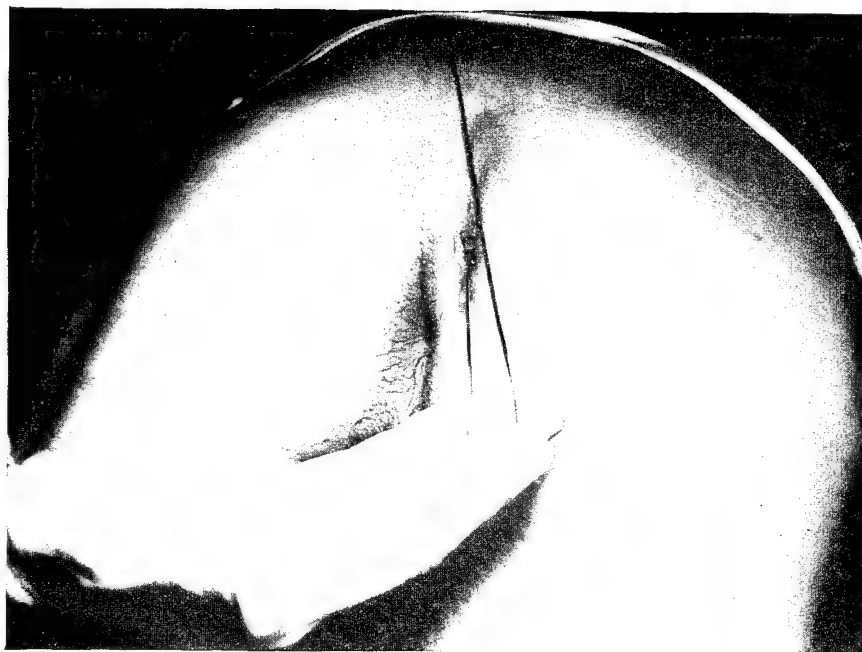


FIGURE 33.—Fecal fistula into extraperitoneal segment of rectosigmoid through rifle wound of buttocks; probe indicates depth of fistula. A double-barreled loop colostomy created in the descending colon immediately after injury required revision and complete separation of the stoma to prevent continued contamination of the fistula. Spontaneous healing of the fistula followed. The colostomy was later closed by direct anastomosis within the peritoneal cavity.

In a small number of cases, the colostomy was not functioning satisfactorily when the patients were received in Zone of Interior hospitals, and prompt revision or relocation was required. A colostomy placed posteriorly in the sacral region, for instance, was relocated anteriorly, in the descending or sigmoid colon. When there was persistent contamination of the buttocks or a persistent perineal fistula (fig. 33), secondary colostomy was necessary to accomplish defunctionalization of the lower rectal segment. The secondary opening was preferably placed proximally in the transverse colon (fig. 34), a site which many surgeons preferred for primary colostomy in injuries of the pelvic colon.

Colostomies performed by surgeons working under the stress of field conditions were sometimes not performed with the care and precision possible in civilian hospitals. Holder and Lewison,⁸ who had a large experience in the closure of colostomy overseas, listed the conditions which made reconstructive surgery difficult as follows:

1. The colostomy had been placed so near the costal margins or the iliac crest that osteomyelitis was an almost inevitable complication (fig. 35).

⁸ Holder, H. G.; and Lewison, E. F.: Management of Colostomies Performed for War Injuries. *Ann. Surg.* 126: 253-261, September 1947.

2. The colostomy had been placed too close to a coexisting cystostomy.

3. The colostomy had been created through the exploratory incision, without adequate mobilization of the bowel. This error, which was most often evident in colostomies of the transverse colon, was likely to be followed by retraction of the stoma, infection of the abdominal wall, intraperitoneal infection, sinus formation, and wound dehiscence. Wound infection, in fact, was almost inevitable because of the practice in military surgery of removing the clamps from the bowel immediately. This was necessary precaution, for, in the rush of work, they could easily be overlooked, and obstruction could occur as a result; but when it was carried out in a colostomy created through the exploratory incision, feces promptly spilled over the fresh wound.

4. The colostomy was created through the wound of entry or exit (fig. 36). This technique was almost invariably followed by infection, which frequently went on to spreading cellulitis.

5. The spur in a Mikulicz colostomy was sometimes too short because the loops had been insufficiently mobilized. As a result, the bowel retracted, and the loops became rotated or partially obstructed.

6. Edema or necrosis sometimes complicated loop colostomies because glass rods or heavy rubber tubing had been used to support an inadequately mobilized



FIGURE 34.—Double stoma in transverse colon, with complete division of bowel. The mucous membranes, however, are still in contact, and the distal segment of the colon remains contaminated. Note the extensive abdominal incisions, the result of multiple surgery.

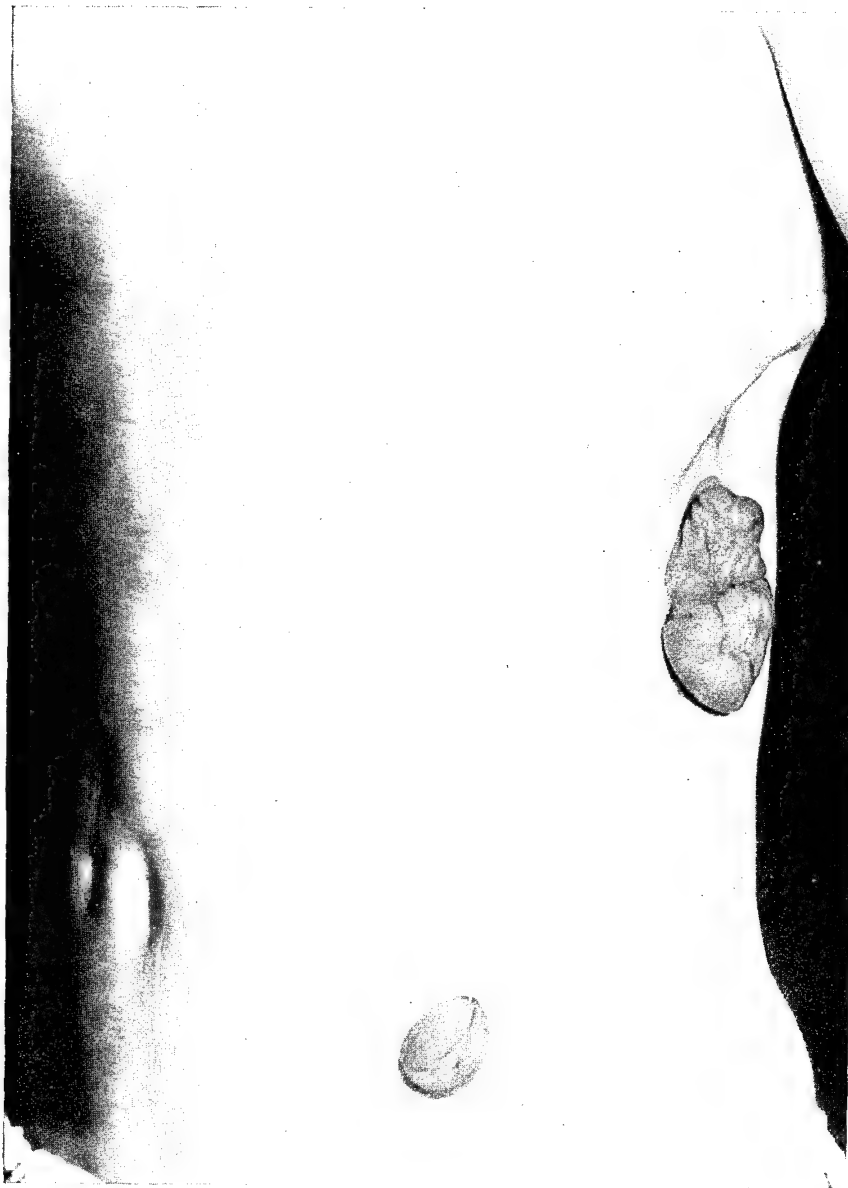


FIGURE 35.—Extensive injuries of descending colon, for which resection was necessary at first operation after wounding. Implantation of proximal end into wound of entrance in flank; distal end has been brought out through inguinal incision. The splenic flexure was liberated by intra-abdominal manipulation to permit primary anastomotic closure.

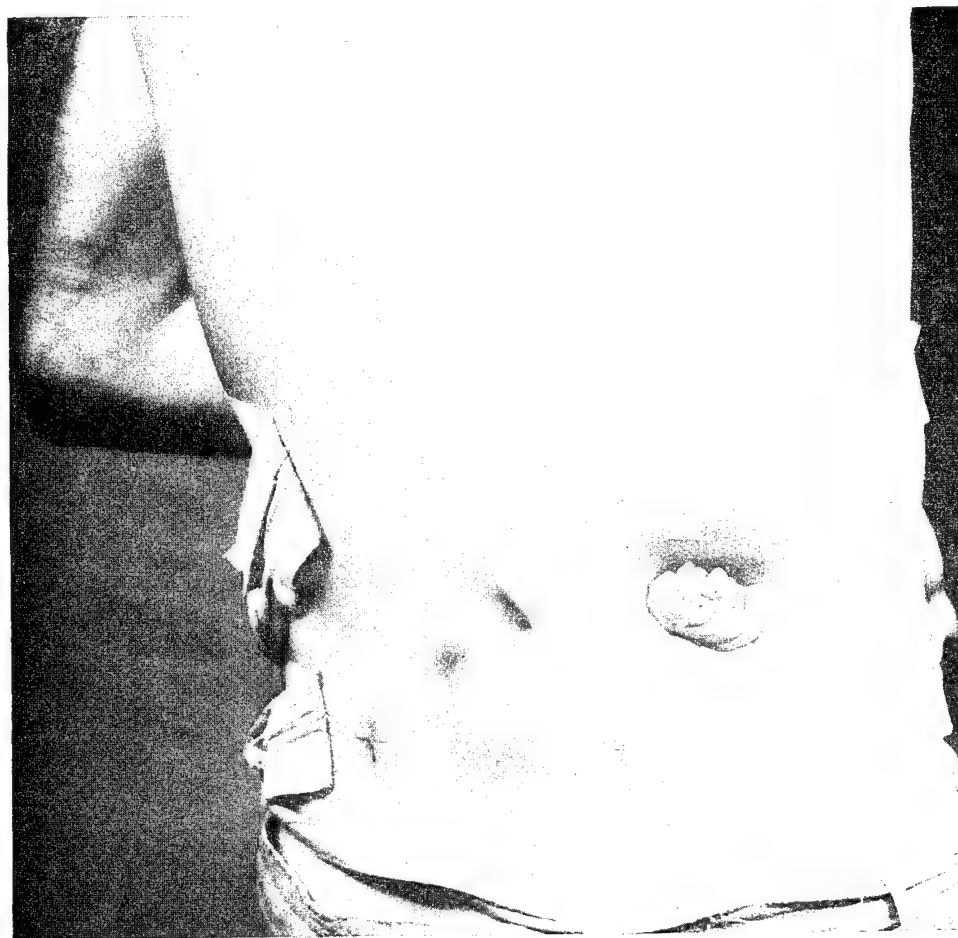


FIGURE 36.—Lumbar colostomy following exteriorization of cecum and ascending colon in wound of flank. The lumbar region is not a location of choice for colostomy, but in this instance function was satisfactory. Closure was effected at an extensive intra-abdominal operation, by ileotransverse colostomy.

loop. If the incision through which the bowel had been brought out was too short, constriction of the bowel, with partial dysfunction of the colostomy, was a likely result.

7. The openings in loop colostomies were sometimes unnecessarily large (fig. 37). Often they had been created in the transverse axis of the bowel rather than the longitudinal axis.

8. Complete diversion of the fecal stream had sometimes not been accomplished (fig. 38). This was essential in wounds of the rectum and extensive wounds of the rectosigmoid, with associated injury to the bladder, urethra, and bony pelvis.

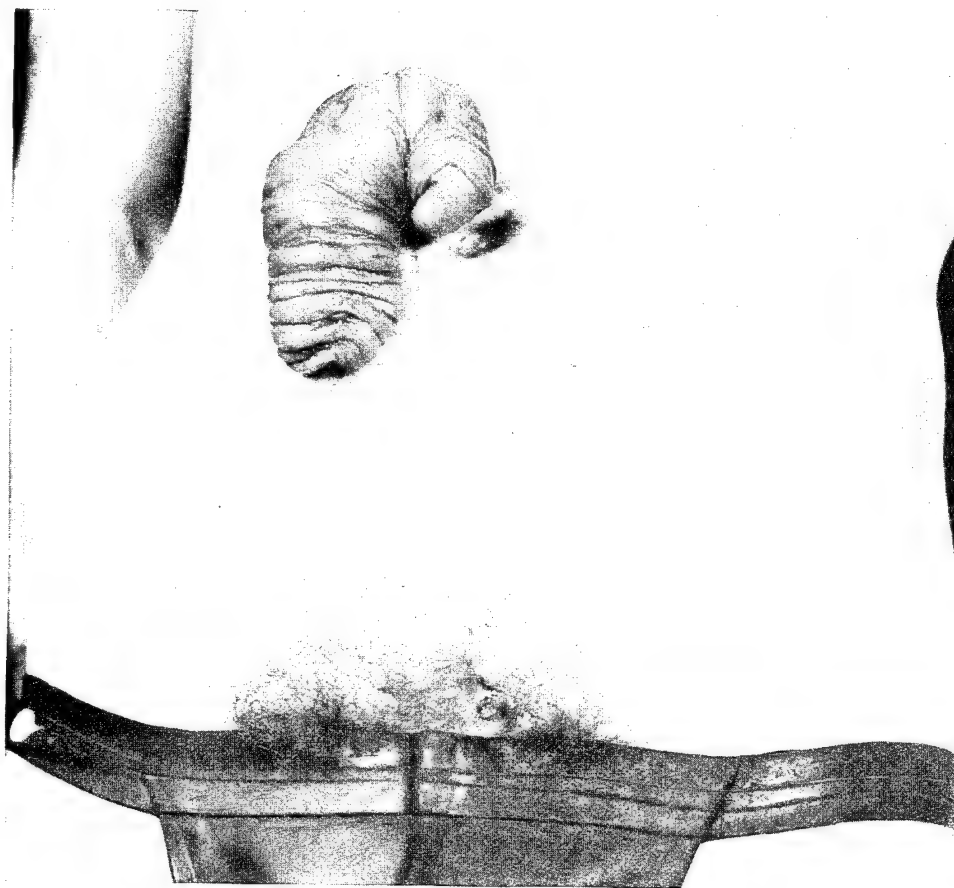


FIGURE 37.—Excessive protrusion of transverse colon and eventration of mucous membrane with incomplete division of bowel. The opening in the abdominal wall is also unnecessarily large. This patient sustained an injury of the perineum, with loss of urinary control. After reduction of the internal herniation of the mucosa, the colostomy was closed by primary anastomosis without too much difficulty.

9. Drainage of the retroperitoneal and pelvic spaces had been omitted in some cases and was not adequate in others. Drainage through the track created by the missile was almost never adequate.

In addition to the technical errors just listed, other errors were observed. The use of sutures which were too tight and the inclusion of the mesenteric artery in the suture of the spur could cause tension, torsion, and constriction of the bowel, with resulting impairment of the circulation. Thrombosis was also a possible complication. Hernia might develop when too large a segment of the bowel was used for the colostomy. Partial obstruction could follow too tight closure. Eventration of the ileocecal area was a possibility in wounds of the cecum.

Infection.—Infection always introduced serious preoperative difficulties. It could arise, as just observed, in dysfunction of the colostomy. It could also originate in a number of other ways. Sometimes abscesses in the chest or the abdomen failed to resolve completely. Infection frequently occurred along persistent fistulous tracts, particularly when osteomyelitis was a complication or a foreign body had not been removed. Fistulas which had healed spontaneously or which had been closed in overseas hospitals sometimes broke down and became infected because the fecal stream had been incompletely diverted and the tract had become contaminated. In cases of persistent infection, the cause had to be sought for and eliminated and adequate drainage established. This often required an extensive surgical procedure (pp. 352, 353).

Fecal fistulas.—Fecal fistulas were always troublesome and were sometimes the cause of serious preoperative difficulties. This was particularly true of fistulas of the small bowel and fistulas in the sacral region. Urinary fistulas could also be very troublesome.



FIGURE 38.—Sigmoid colostomy (incomplete division of bowel), with eversion of mucous membrane, performed to sidetrack fecal current from fecal fistula in buttocks.

In some instances, because of a surgical error, the artificial anus had been constructed in the terminal ileum or the ileum had been used to form the colostomy in combination with the large bowel. The spur might consist of colon and ileum, or a single or a double mucous fistula might be created following end-to-end or side-to-side anastomosis between the ileum and the colon. Fistulas of the jejunum or the duodenum were usually the result of the original injury or of surgical attempts to repair it.

Fistulas of the small bowel produced irritation or actual digestion of the skin. Sometimes the process was extensive. All methods used to protect the contaminated areas were likely to be unsatisfactory. Moreover, because of continuous drainage and the loss of essential elements from the gastrointestinal tract, patients with fistulas were often gravely emaciated. Immediate closure of the fistula was therefore indicated.

Small, uncomplicated fistulas could be eliminated by inversion of the intestine into the lumen. In some complicated cases, a shunting or sidetracking procedure had to be employed, with anastomosis of the ileum to the descending or transverse colon proximal to the fistula, by either the side-to-side or the end-to-end technique. Later, the colostomy could be closed by some one of the methods shortly to be described, or, if it was indicated, resection of the intervening ileum and colon could be carried out. Improvement following closure of a fistula in the small bowel was usually prompt and was often dramatic.

Patients with fistulas in the sacral region usually arrived in the Zone of Interior in poor condition, as the result of chronic sepsis. In perhaps half of all wounds of the rectum, the bony structure of the pelvis had been damaged also, and osteomyelitis was a frequent complication. As a rule, it was extensive, involving the sacrum, the coccyx, the wings of the ilium, or the upper portion of the femur. The joint cavities were also often involved in the infection. The fistula was persistently contaminated because the distal segment of the intestine had not been completely defunctionated, and the fecal drainage enhanced the bone infection. Finally, foreign bodies, which in this location are difficult to localize accurately and which were therefore often left in situ, frequently served as foci of infection. The complete removal of all foreign bodies, while extremely important at the first operation, was by no means as simple as it may sound. Pieces of clothing and gauze and bits of equipment which were not radiopaque were extremely difficult to visualize and identify. If all extraneous material was not removed, persistence of infection in fistulous tracts was inevitable. The vicious circle thus set up was extremely difficult to interrupt.

If a foreign body was not present or if osteomyelitis was not a complication, a fistula in the sacral region occasionally healed spontaneously, even when there was persistent contamination of the distal segment of bowel. More frequently, prolonged treatment was necessary. It included daily irrigations of the fistula with physiologic salt solution or some other solution, the admin-

istration of a sulfonamide, and measures directed toward improvement of the general condition. These measures, although they were occasionally successful, were not desirable definitive treatment for a fecal fistula. For one thing, it was impossible to determine in which cases they would succeed. For another, even an apparently successful result of expectant treatment was not always permanent. The fistula was likely to reopen, the mucous membrane of the bowel tended to evert into the fistulous tract, and other undesirable consequences could ensue.

Experience soon showed that even a short and direct fistulous tract which traversed bone would not heal until three conditions had been fulfilled: (1) The fecal stream had to be completely diverted; (2) all dead bone, including the coccyx and parts of the sacrum, had to be removed; and (3) all scar tissue which prevented obliteration of dead spaces also had to be removed. Paradoxically, healing of long, tortuous fistulous tracts which traversed bone sometimes occurred when only expectant measures were used, but the course of treatment was long and tedious and the results were so uncertain that surgery was always the preferred method.

The first step in the treatment of a fecal fistula was diversion of the fecal stream, either by revision of the colostomy or by creation of a secondary colostomy placed proximally in the transverse colon. Revision was best accomplished by some modification of the Devine technique (fig. 39), in which the openings would be separated by a bridge of skin. The next steps were removal of any foreign bodies in the region of the fistula and adequate unroofing of the entire tract from its external opening down to the rectum. Unroofing was often difficult and hazardous because of the extensive thickening and resulting rigidity of the rectal wall and the adjacent tissues. Incisions into the peritoneum lateral to the rectosigmoid helped to free the rectum. Eversion of the rectal mucosa into the fistula, which had usually occurred, was corrected by excision of the involved mucosa or by inverting it into the rectal lumen. The final step of the operation was excision of scar tissue and of the coccyx and parts of the sacrum, together with removal of all foreign material such as metal, bits of clothing or equipment, and surgical gauze, which was sometimes still present since it had been applied as a first-aid measure.

The extensive surgery required for the repair of sacral fistulas, in addition to the tissue lost because of the ravages of infection, usually caused serious losses of soft tissue. Plastic repair was therefore frequently necessary. The preferred technique was to perform a staged operation, swinging muscle flaps across the debrided tract and then using full-thickness skin grafts.

Fistulous communications between the intestine and urinary tract were fairly frequent and had to be dealt with by various measures before closure of the colostomy could be attempted. They were sometimes kept open by obstruction caused by urinary calculi or by adhesions. The proctoscopic and cystoscopic studies which were essential had to be carried out with great care because of the induration and scar tissue present in both rectum and

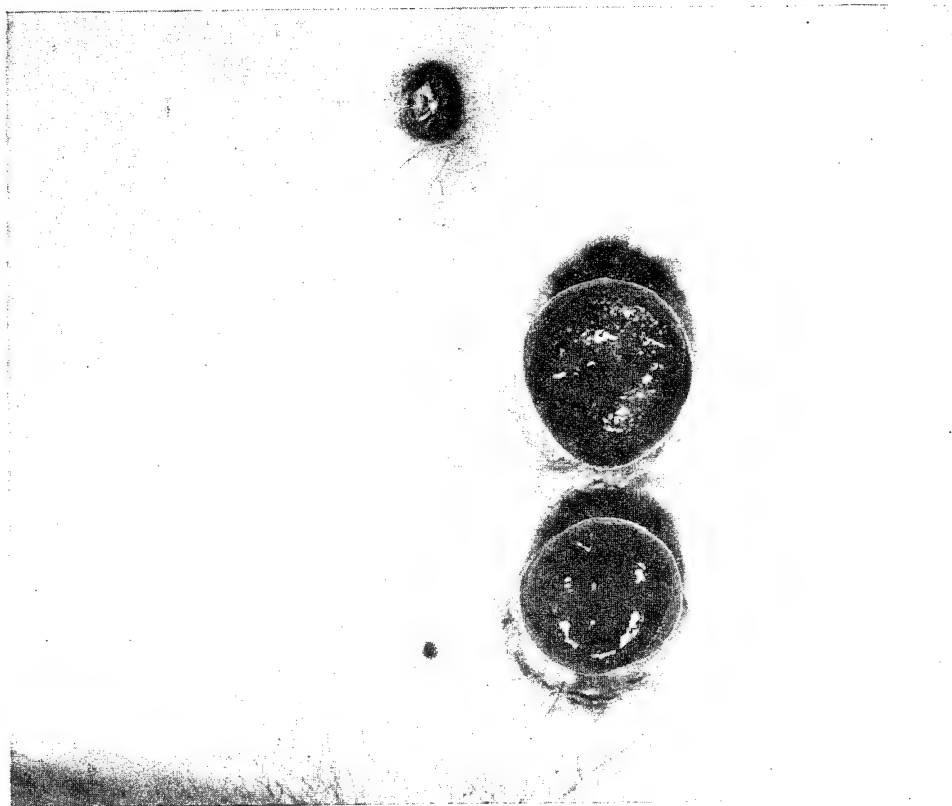


FIGURE 39.—Revision of sigmoid colostomy by modified Devine technique to provide complete diversion of fecal stream from fistula in buttocks. The colostomy was closed by direct anastomosis within the abdominal cavity.

bladder. Barium enemas and the injection of the fistula with radiopaque substances were useful in determining the limits of extension of the lesions.

If the ostium was not too large, conservative therapy was usually given a trial in urinary fistulas, in an attempt to promote healing at the point of origin. If urinary calculi or adhesions were responsible for failure of healing, conservative measures were useless, and surgery was indicated. If the fistula communicated with the rectum in the lower segment or near the anus, a plastic procedure (the Stone operation) was almost always required. The patients in this group were transferred to Walter Reed General Hospital for the necessary surgery.

In addition to the more usual types of fistulas, bizarre types were not uncommon. They included fistulas extending through the vertebral column, through the diaphragm and chest, into the acetabulum, and into the urethra. The latter type was easily diagnosed by the passage of gas through the penis.

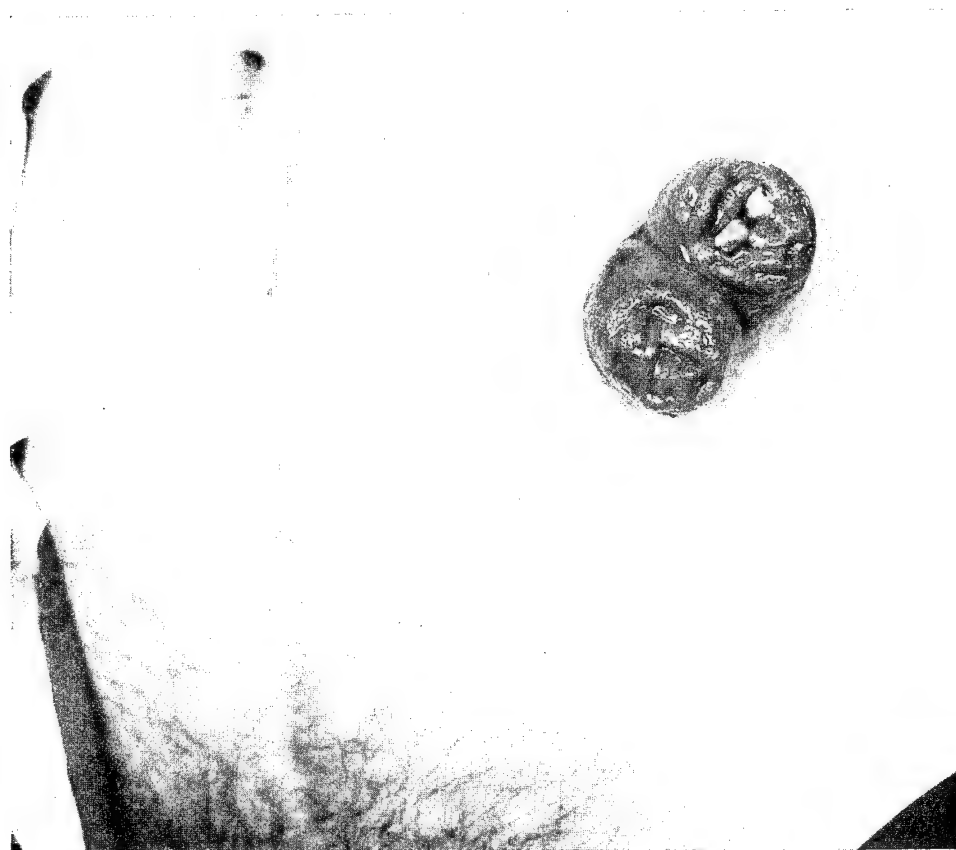


FIGURE 40.—Left inguinal colostomy with incomplete division of bowel following exteriorization of wounded descending colon. This frequently used type of colostomy functioned satisfactorily and was easily closed by direct anastomosis. Application of spur-crushing clamps was hazardous because interposition of loops of small intestine occasionally occurred.

Preoperative Regimen

The time interval between reception of the patient in a Zone of Interior hospital and closure of the colostomy varied widely, sometimes because of the patient's own status and sometimes, particularly during periods of intense activity, because of crowded hospital conditions. The categorical statement can be made, however, that in no instance was any harm caused by the delay. In fact, one of the strongest points in favor of handling wounds of the colon by exteriorization and colostomy was the ability of patients thus treated to travel long distances without harm and to wait indefinitely for closure of the stoma without deterioration of their status.

The relatively few patients who were received in Zone of Interior hospitals without associated injuries, free from infection, and with colostomies which were functioning satisfactorily were prepared for operation at once and were operated on as soon as possible. These patients were the exceptions. The great majority presented preoperative problems of one sort or another (p. 343) and required a more extensive preparatory regimen in addition to special measures suitable to their individual difficulties.

As soon as patients were received in Zone of Interior hospitals, they were taught to take care of their own dressings. Those who were able to be ambulatory were required to be. Associated injuries were treated as necessary. Whenever it was practical, arrangements for furloughs were made. The psychologic stimulus of a return to their homes and families amply compensated for any delay in closure of the colostomy.

Operation was not undertaken in any case until the colostomy was functioning satisfactorily (fig. 40) and certain other criteria had been met:

1. The nutritional status must be restored to a level at which surgery would not be attended with any undue risk. A completely normal status was desirable but was not regarded as essential.
2. The healing of associated injuries must have advanced to a stage at which ambulation was possible.
3. Fecal fistulas must have been healed for at least 8 to 12 weeks.
4. The skin about the colostomy must be in optimum condition.

Special measures.—The first essential of the general preoperative regimen was attention to the colostomy. Many patients, after trips from overseas which sometimes occupied a considerable time, were received with large amounts of inspissated fecal material in the distal loop. These accumulations were removed by irrigations of distilled water, physiologic salt solution, or solutions containing acriflavine, potassium permanganate, or penicillin. After the distal loop had been completely cleaned out by these means, irrigations were carried out three to five times weekly, with two objectives, to restore the tone of the loop and to increase the size of the opening, which had often become much smaller in the weeks or months since the colostomy had been created.

The second essential of preoperative preparation was the protection of the skin from fecal discharges. This was particularly important if irritation was already present. The best results were accomplished with dressings of kaolin or aluminum paste.

The third essential of the general regimen was restoration of the nutritional status to a level approaching normal. The caloric content of the diet was maintained between 3,500 and 5,000 calories daily. There was special emphasis on the protein component, which ranged between 125 and 175 gm. daily. Transfusions of plasma and whole blood were given as indicated. Supplementary vitamins, iron, and liver extract were also given as necessary.

Immediate preoperative preparation.—Special preparations for surgery were begun several days in advance of operation. The routine varied in details

from hospital to hospital but was always based upon the following general policies:

1. Routine laboratory tests were conducted, and operation was postponed if the chlorides, protein, and vitamin-C levels of the blood were not approximately normal. The prothrombin time was determined the day before operation, and closure of the colostomy was deferred if it was not satisfactory. Roentgenograms of the abdomen were made to demonstrate possible retained foreign bodies, and barium-enema studies were made to exclude possible intestinal obstruction.

2. A sulfonamide drug (usually Sulfasuxidine (succinylsulfathiazole), phthalylsulfathiazole, or sulfaguanidine) was given for 5 days before operation in doses of 1 gm. six times daily. If local irritation was evident on the skin during the course of treatment, kaolin or aluminum paste was applied.

3. Vitamin K was usually given the day before, and the day of, operation. Paregoric was ordered just before the patient was taken to the operating room.

4. The ample diet previously provided was discontinued 3 days before operation and was replaced by a low-residue diet, which was, however, equally high in protein content. Only clear fluids were permitted during the 24 hours immediately before operation.

5. Irrigation of both loops of bowel was continued up to the day of operation. On the morning of operation, irrigations of sterile physiologic salt solution were continued until they returned perfectly clear.

Anesthesia

Practically all methods of anesthesia were used to close the colostomies in this series, but fractional instillation of an anesthetic drug into the spinal canal was perhaps the most favored technique. Pentothal Sodium was sometimes used for induction but was never used for the entire procedure. Local anesthetic agents were avoided, because of the risk of spreading infection.

Technical Considerations

Official directives did not specify any standard procedure for the closure of a colostomy. This left the surgeons at the various general hospitals free to develop their own methods, under the general supervision of consultants. Since 106 surgeons are known to have closed the 2,198 colostomies managed in the general hospitals in the United States, the range of detailed techniques was correspondingly wide, although only a few basic techniques were employed.

During the early months of American participation in the war, the tendency was to employ extraperitoneal methods of closure. Later, intraperitoneal techniques became increasingly popular, for two reasons:

1. In spite of careful efforts to avoid opening the peritoneal cavity, it was frequently entered during extraperitoneal operations.

2. It was found that undesirable consequences did not follow deliberate or accidental invasion of the peritoneal cavity during the closure of a colostomy.

In the 1,813 cases in which the technique employed in closing colostomies in the Zone of Interior hospitals was stated, the intraperitoneal approach was used 1,055 times (58.2 percent) and the extraperitoneal approach 758 times. At Rhodes General Hospital (series C), all 96 patients were treated by the intraperitoneal technique. In the 437 cases in which this information was available in series A, the intraperitoneal approach was used 186 times and the extraperitoneal 251 times.

Information concerning the precise technique of closure was available in only 1,331 of the 2,198 operations performed in Zone of Interior hospitals. End-to-end anastomosis was employed in 642 cases (48.2 percent). The Pauchet type of anastomosis was employed in 22 cases, all at the same hospital, and other measures, including spur crushing followed by closure, were employed in the remaining 667 cases. At Rhodes General Hospital, simple closure was performed in 60 cases, end-to-end anastomosis in 42, and ileocolostomy in 6. There were 12 multiple operations in this series. The procedures used in the special group of hospitals which make up series A are presented in the following table.

TABLE 98.—*Techniques of closure of colostomy and associated operations in 464 battle-incurred wounds of large bowel (series A)*¹

Procedure	Cases	Procedure	Cases
Simple closure.....	119	Ileocolostomy.....	11
End-to-end anastomosis.....	316	Anal reconstruction.....	10
End-to-side anastomosis.....	3	Closure distal loop.....	3
Side-to-side anastomosis.....	9	Crushing of spur.....	167
Pauchet anastomosis.....	22	Reconstruction of spur.....	3
Resection.....	11	Coccygectomy.....	10

¹ This information is not available in 17 cases.

Information concerning the technique of closure employed in the 180 cases (series B) in which closure was accomplished overseas was available in only 76 cases. Some method of anastomosis was used in 5 cases, and spur crushing and closure were employed in the other 71.

Extraperitoneal operations.—Simple closure of the colostomy was employed in approximately 60 percent of the cases in which the approach was extraperitoneal. This was an entirely adequate operation when the stoma was small. In such cases, the technique used at the original operation had been tube or tangential colostomy or loop colostomy without division of the posterior wall of the colon. The preferred suture material was catgut of small size. The

suture line was inverted at least once. If spur crushing had been necessary, closure of the anterior wall of the colon was the final step of the operation.

End-to-end anastomosis was used in about 30 percent of the cases managed by extraperitoneal operation. Side-to-side or end-to-side anastomosis was employed in the other 10 percent. These techniques all proved satisfactory in the cases—which were not too numerous—in which it was possible to mobilize the loops of bowel adequately outside of the abdomen, and they had the great advantage of eliminating all risk of postoperative intestinal obstruction at the suture line.

Intraperitoneal operations.—When intraperitoneal closure of a colostomy was contemplated, no attempt was ever made to crush an existing spur. Instead, the limbs were dissected free, and sufficient space was thus provided for any type of anastomosis. When the peritoneal cavity was to be entered, special efforts were also made to free the area of adhesions. These dense adhesions, which often bound the bowel intimately to the anterior abdominal wall, many times had to be treated by sharp dissection. The objective of these maneuvers was to leave the repaired intestine entirely free in its normal location.

Simple closure of the anterior wall of the bowel was a satisfactory technique if the posterior wall of the colon remained intact. If it was not intact, end-to-end anastomosis was the preferred technique, though a number of surgeons had good results with side-to-side and end-to-side anastomoses. The Pauchet technique produced excellent results in the single hospital in which it was used. In this technique, longitudinal slits are made in the proximal and distal loops after they have been fixed with a posterior suture, and side-to-side anastomosis, as in a Finney pyloroplasty, is used to reconstruct the bowel. The large stoma thus created at the line of anastomosis serves as a safeguard against possible future obstruction at this point.

Ileotransverse colostomy was used in a small number of cases in which damage to the right half of the colon and the small intestine had been followed by infection and massive destruction of soft tissues and in which sidetracking of the fecal current had been necessary. The operation was performed by joining the ileum, above the injury, to the transverse or descending colon. Closure of the original colostomy by end-to-end anastomosis was then possible. Leakage of irritating material seldom occurred, and failure was unusual. In most cases, because of the multiple openings, resection of some portion of the intestine was necessary. Usually the portion resected was in the ascending, transverse, or descending colon. If extensive damage had made two or more colostomies necessary, it was frequently simpler, when closure was undertaken, to resect the middle segment of the intestine and restore intestinal continuity by an end-to-end anastomosis.

Adjunct procedures.—Herniations in the fascia (p. 345) varied from slight weakening of the tissues, which permitted insignificant protrusions of the peritoneal contents, to extensive openings which required plastic repair. Unless there was some good reason for terminating the operation after

closure has been accomplished, the repair was performed at the same time the stoma was closed. Catgut, silk, or cotton was used for sutures, depending upon the preference of the individual surgeon. The results of these operations were generally good.

Drainage was seldom necessary when the stoma was closed, and instances were on record in which it was clearly harmful. The risk of placing drains between layers of fascia was typified by the slough which occurred in two cases in a hospital in which this technique was popular.

In a few hospitals, it was the custom to close the wound through the fascial layer at the first operation and complete the closure 2 or 3 days later.

Postoperative Regimen

Although practices varied from hospital to hospital, the postoperative regimen after closure of a colostomy was deliberately kept as simple as possible. In some hospitals, nothing was given by mouth for from 24 to 48 hours. In others, fluids were given promptly and soft food shortly afterward.

The fluid balance and nutritional status were maintained by the parenteral administration of dextrose solution, physiologic salt solution, casein hydrolysate, plasma, and whole blood, according to the necessities of the individual case.

Constant intestinal decompression by the Wangenstein technique or by means of the Miller-Abbott tube was instituted in all cases in which distention was considered a possibility. These methods were most frequently employed after operations on the right half of the colon.

The sulfonamide which had been employed before operation was continued for 5 to 7 days afterward. When penicillin became available, it was used by the intramuscular route in all cases in which infection seemed a possibility. The dose was 100,000 units every 4 hours. Toward the end of the war, when streptomycin became available, it was used with apparently good results in gram-negative infections.

When vitamin K had been used before operation, it was usually continued for 3 days or more after operation.

Anal dilatation was carried out daily for 5 days after operation.

Early ambulation was not practiced uniformly, but there were no untoward results in any of the hospitals in which it was permitted.

Before the patient was discharged, all the laboratory determinations which had been carried out before operation were repeated. Roentgenologic studies were also carried out, to establish the patency of the anastomosis and as a final check against overlooked foreign bodies.

Postoperative Complications

The discussion of postoperative complications is confined to the 464 cases (series A) from the group of hospitals which supplied especially full details on

the questionnaires from which the data on closure of colostomy were secured. They are typical of the complications which occurred in all hospitals.

In these 464 operations, leakage occurred at the site of closure in 70 cases (about 15 percent). It was usually insignificant, and healing occurred promptly under conservative management. In 23 cases, however, secondary closure was necessary, and, in a few instances, multiple operations were necessary before the intestinal wall was securely closed. One patient required seven operations.

Local infection occurred in 39 cases (8.4 percent). It varied from slight exudation to extensive abscess formation, and in a few cases was associated with wound dehiscence. Clostridial myositis occurred in 1 case, and in 2 others the infection was apparently the result of amebic infection.

Hemorrhage occurred in six cases. It was usually manifested by local bleeding. In one case, the formation of a large hematoma was followed by abscess formation. In two instances, bleeding occurred in patients who had received Sulfasuxidine. Although the bleeding was controlled without difficulty in all six cases in which it occurred, the potential seriousness of this complication was obvious.

Paralytic ileus occurred only twice, but in one instance it was associated with massive distention; secondary surgery was eventually required. The negligible incidence of ileus in this series as well as in the larger total series can be attributed to the prophylactic institution of constant intestinal decompression in so many cases.

Intestinal obstruction of some degree was apparent clinically in about 10 percent of all cases. It was usually slight and transient and subsided spontaneously; in such cases, the cause was assumed to be edema at the anastomosis or the suture line. Adhesions were usually responsible for mechanical intestinal obstruction, though in a small number of cases it occurred because so much of the bowel wall had been infolded that an actual diaphragm had been created across the intestinal lumen. Although the 10-percent incidence of postoperative intestinal obstruction was undesirably high, only 3 of the 11 deaths which occurred in Zone of Interior hospitals after closure of colostomy could be attributed to it. Advocates of the open abdominal approach contended that the risk of obstruction was less when this technique was used.

Peritonitis occurred in 8 cases, 1.8 percent of the total number in series A. In 1 or 2 instances, the infection was mild and localized. In the other cases, peritoneal involvement was generalized, and five deaths were attributed to it. In 2 of the 3 surviving patients, abscess formation subsequently occurred, in the pelvis and the subphrenic space, respectively, and surgical drainage was necessary.

There was only one instance of thrombophlebitis. The infrequent occurrence of this complication was attributed by many surgeons to the emphasis placed upon movement about the bed immediately after operation, as well as to the practice, in many hospitals, of early ambulation.

Fatalities

Eleven deaths are known to have followed closure of the colostomy stoma in the 2,198 cases cared for in Zone of Interior hospitals (0.5 percent). They were about equally distributed between the intraperitoneal and extraperitoneal techniques. Five, as just noted, were caused by peritonitis and three by intestinal obstruction. Liver failure, mesenteric vascular occlusion with gangrene of the bowel, and inanition accounted for the three remaining deaths.

Two other deaths occurred before operation, in patients who were being prepared for surgery. In each instance, the cause was an intractably poor nutritional status and the resulting inanition. The cause of the single death which occurred in the 180 colostomies closed in overseas hospitals is not known.

The 12 deaths which followed surgery in these 2,378 closures thus represented a case fatality rate of 0.5 percent.

COMMENT

A study of the 2,378 patients who underwent closure of colostomy in this composite series indicates that, from the standpoint of the initial phase of management overseas, casualties with wounds of the colon fared better in World War II than in any previous war for which records are available. They were removed from the battlefield with remarkable speed. They were prepared for operation with efficient resuscitative measures and without loss of time. Finally, the routine practice of colostomy in wounds of the colon saved innumerable lives which would undoubtedly have been lost in any previous war. The principle of exteriorization of the damaged colon was so firmly established in World War II that no further controversy can possibly arise concerning its use in any case in which the bowel can be sufficiently mobilized to permit it. It is a simple procedure, which can be carried out safely and promptly by surgeons of limited experience. It entirely obviates the need for difficult surgical decisions and for extensive resections and anastomoses in patients whose status is poor and who must be operated on under field conditions. Certain aspects of the operation deserving special comment are given in succeeding paragraphs.

Diversion of the fecal stream.—One of the items on the questionnaire circulated in general hospitals of the Zone of Interior concerned the possibility of accomplishing total diversion of the fecal stream with an ordinary colostomy. There was not complete agreement in the 19 replies received. Four surgeons did not think that it could be accomplished with a tube or tangential colostomy. Four thought that it could not be, or probably could not be, accomplished with a loop colostomy, one thought that it could be, and one other thought that it probably could be. Four thought that it could be accomplished by spur colostomy or probably could be, and one thought that it could not be. The four remaining surgeons thought that total diversion of the fecal stream could be accomplished with a Devine colostomy. The infer-

ence, therefore, is that only by the use of the Devine technique (fig. 39, p.354) or some other special technique (fig. 41) in which there is actual separation of the stoma could one be absolutely certain of complete diversion of the fecal stream. Some surgeons regarded the creation of a second colostomy of the spur type, proximal to the sigmoid colostomy, as the better method of preventing contamination of the distal segment. The transverse colon was the preferred location for the second colostomy.



FIGURE 41.—Extensive damage to descending colon, with complete severance of gut, requiring resection at first operation after wounding. The end of the colon was implanted into the abdominal incision, creating a satisfactory colostomy. Closure by primary anastomosis after reopening abdominal cavity.

There was also some difference of opinion concerning the absolute necessity for diversion of the fecal stream in the event that a fistula existed distal to the colostomy, particularly in the sacral region or the buttocks. The majority of the 62 surgeons who replied to this question considered it absolutely essential, or advisable, or desirable. The others did not consider it necessary. There was general agreement that a short, direct fistulous tract would not heal if fecal contamination continued, particularly if the tract traversed bone which was the site of an osteomyelitis. There was also general agreement that even if long, tortuous tracts healed under conservative management, sometimes without complete diversion of the fecal current, expectant treatment was not justified. The healing process could be expected to cover many months, and healing was unlikely until dead bone and foreign bodies had been removed. The consensus was that under these circumstances there were three courses of action: (1) Complete decontamination of the fistulous tract by revision of the colostomy into a modified Devine colostomy; (2) creation of a proximal colostomy in the transverse colon; or (3) closure and inversion of the fistula into the rectum, with complete unroofing of the tract, excision of everted rectal mucosa, and removal of all foreign bodies and of the coccyx or part of the sacrum.

Technical considerations.—The trend, as the war progressed, to substitute intraperitoneal for extraperitoneal techniques of closure has already been mentioned. The untoward results which sometimes followed crushing of the spur had much to do with the change in practice. In civilian surgery, the management of the spur presents no problem, for the surgeon who creates the colostomy crushes it himself. In military practice, the surgeon who constructs the colostomy almost never crushes the spur. The hundreds of patients admitted to general hospitals in the Zone of Interior with unclosed colostomies were operated on by surgeons who, however experienced they might be, had no knowledge of the initial surgery in any case beyond what was contained on the field medical record. These data were often entirely inadequate. Even when the records were reasonably complete, the conditions were not at all the same as if the surgeon who was to crush the spur had been responsible for the creation of the colostomy or had at least observed its creation. Furthermore, the unavoidable haste with which many operations were necessarily performed in forward hospitals, combined with the limited experience of some of the operating surgeons, militated against the construction of an ideal spur, especially when it was known that a simple loop colostomy would suffice.

In addition to these fundamental considerations, unfortunate experiences in dealing with poorly constructed spurs played a large part in the substitution of the intraperitoneal for the extraperitoneal technique. The application of a clamp or an enterotome often produced severe pain, nausea, and vomiting. Peritonitis sometimes followed the accidental crushing of large mesenteric vessels. Other complications included infection, fistula formation into the ileum or jejunum, paralytic ileus, intestinal obstruction, and prolonged edema

and cyanosis of the intestinal mucosa. In two instances in this series, benign neoplasms occurred at the site of the spur.

Most serious of all, rotation of the loops had taken place in nearly a hundred cases in the total series, and the existing relationships could not be determined before the enterotome was applied. As a result of this combined experience, more and more surgeons abandoned attempts to crush the spur and resorted, instead, to intraperitoneal closure of the colostomy.

The data available in this analysis do not supply adequate statistical proof concerning the relative frequency of postoperative complications after extraperitoneal versus intraperitoneal colostomy closure. The clinical impression was, however, that complications were fewer when the intraperitoneal technique was used. There was considerable logic in this point of view:

1. The peritoneal surfaces had been vaccinated before operation, because the colostomy had practically always existed for months before closure was attempted.

2. All the patients were young and free from organic disease. As a rule, they were in excellent condition except for the colostomy and its complications.

3. Chemotherapy and antibiotic therapy probably played some part in the good results, by preventing invasive infection. Streptomycin was regarded as particularly useful in this respect.

4. With the intraperitoneal technique, the restoration of the bowel more nearly approached normal because the anastomosis could be performed more accurately and all adhesions could be obliterated. At the conclusion of the operation, therefore, the repaired bowel lay free in its normal location, and postoperative intestinal obstruction was less likely to occur.

The experience in this series showed that injuries to the right side of the colon presented special problems, particularly if the small intestine had also been damaged. It was not felt, however, that the use of the small bowel with the colon to create a spur colostomy offered any solution of the problem. Wounds in this area were best dealt with by resection of the damaged cecum or ascending colon, with direct end-to-end anastomosis between the ileum and colon. After this had been done, a single-barreled external mucous fistula was created in the proximal colon.

Injuries of the rectum also furnished special problems. Sacral or perineal colostomy, employed in less than 1 percent of the cases in this total series, was used chiefly when severe damage to the rectum was associated with partial or total destruction of the anal sphincter. Even as a temporary expedient, however, this was not regarded as good surgery. The nursing care in such cases was extremely difficult, irritation of the skin was almost unavoidable, and the patients themselves objected to this type of colostomy for a number of reasons, including purely esthetic reasons.

The best plan in injuries to the fixed portions of the rectum and colon was immediate repair of the anal sphincter, combined with posterior drainage and followed by proximal colostomy, preferably in the transverse or descending

colon (fig. 42). Loop openings were separated, to avoid continued contamination of the distal loop. This precaution was particularly important if the pelvis or the sacrum had been injured or if there had been extensive damage to the rectum or bladder below the peritoneal attachment (fig. 43).

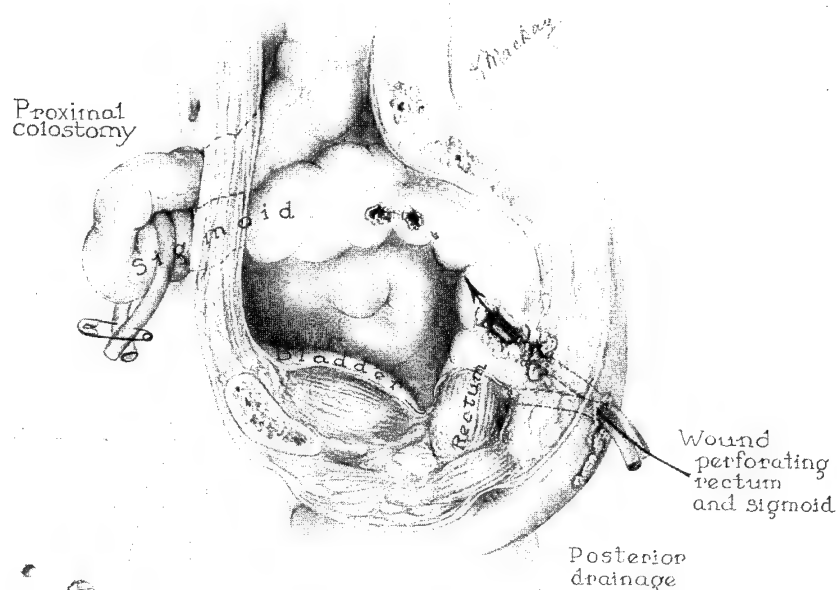


FIGURE 42.—Proximal colostomy in descending colon for wounds of sigmoid and rectum.

After the damaged colon had been resected, the terminal loop was closed and an open proximal loop was used to form the colostomy (insert).

When a patient was received with a sacral colostomy and with damage to the anal sphincter which had not been repaired or the repair of which had been unsuccessful, a secondary colostomy was created at once, in the sigmoid or transverse colon, before plastic surgery on the anus was undertaken. Even if this colostomy had to become permanent, because of failure of repair of the anus, it was possible to close the sacral opening, and the unfortunate casualty was left in much better condition than he had been in after the first operation.

A consideration of the errors observed in the colostomies in this series leads to the conclusion, fortified by the entire experience of World War II, that, in injuries of the colon, the damaged loop should always be brought out through a stab wound placed laterally to the main incision and that it should be fixed in this location by sutures which do not pass through the bowel wall (fig. 44).

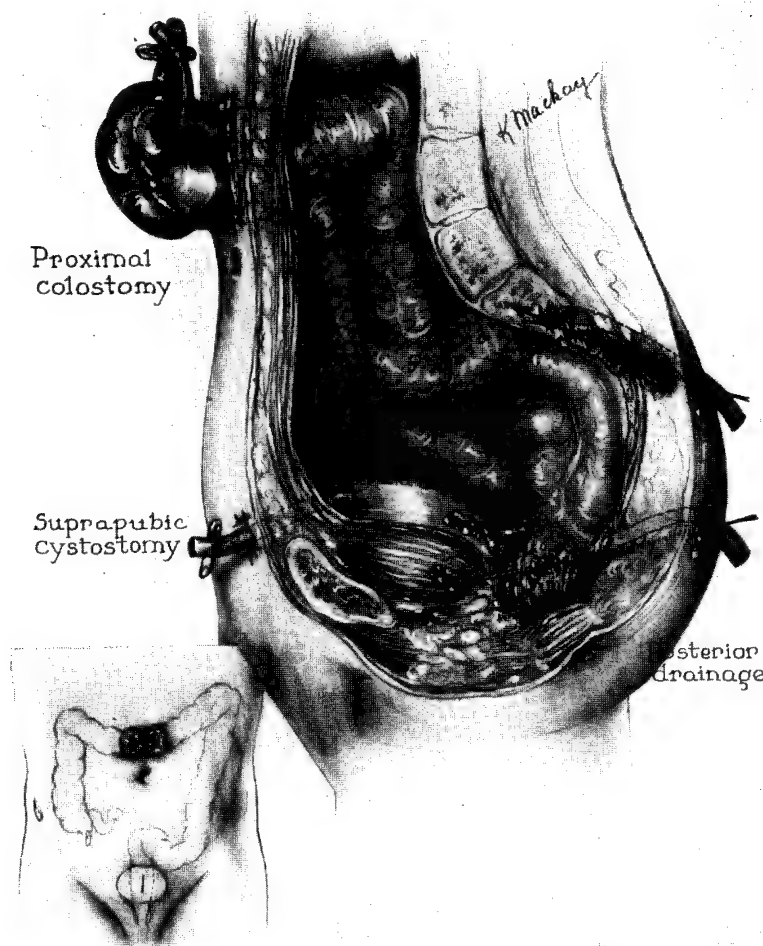


FIGURE 43.—Proximal colostomy in transverse colon for retroperitoneal wounds of sigmoid and rectum. The shell fragment also traversed a sacral vertebra and the bladder. Insert shows final double-barreled colostomy.

Satisfactory support can be provided by a glass tube of the kind in which cat-gut is sterilized or by some similar blunt object placed beneath the mesenteric border. Rubber tubing can also be used. Spur formation is not essential. In fact, observations in Zone of Interior hospitals, and attempts to crush spurs in which the relationship to surrounding structures had changed, suggested that any technique which required creation of a spur might be actually undesirable.

The revisions and relocations of the original colostomies performed in this series would have been entirely unnecessary if the general principles set forth in this chapter had been followed in the creation of the original opening. Furthermore, some, at least, of the problems encountered at every hospital, such as retraction of the loops of bowel, undue protrusion of the bowel through exces-

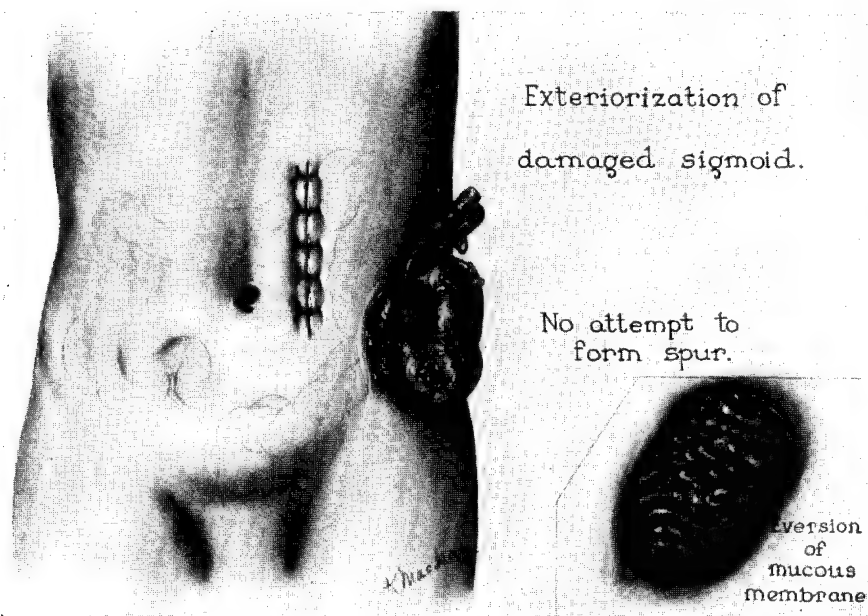


FIGURE 44.—Exteriorization of damaged sigmoid colon. No attempt has been made to create a spur. Insert shows resulting eversion of mucous membrane.

sively large fascial openings, intestinal obstruction caused by adhesions, continued contamination of a distal fistulous tract, and retained foreign bodies, would have presented no difficulties if these principles had been followed.

Chemotherapy and antibiotic therapy.—Although the colon is one of the most heavily contaminated structures in the body, there was considerable divergence of opinion as to the necessity for, and the value of, supplemental chemotherapy and antibiotic therapy in closure of colostomies. One or the other of these methods, and sometimes both, were used in most cases in this total series, but about a third of the surgeons who performed the operations were not convinced of the value of any of these agents, about 10 percent considered them of no value, and a few regarded them as harmful.

Most of the surgeons who used these drugs thought that their chief value, at least as far as the then newly developed preparations Sulfathalidine (phthalyl-sulfathiazole) and Sulfasuxidine were concerned, was to insure a clean intestinal surface at the time of operation. They questioned their antibacterial effect and were inclined to attribute the striking absence of infection in these cases to the fact that sufficient time had elapsed since the first operation to permit some degree of autovaccination of the peritoneal surfaces. In spite of these doubts of the value of the routine use of these agents, it was the general practice to administer Sulfasuxidine and Sulfathalidine orally for several days before operation to all patients who had had peritonitis or intra-abdominal abscesses, as well as to those who were likely to require extensive resection of the colon.

When penicillin and streptomycin became available, they were used on the same indications.

Almost all of the available sulfonamides except sulfanilamide were used in this series, but Sulfasuxidine and sulfaguanidine were the most popular. Sulfathalidine was not available at all hospitals. All routes of administration were employed, including the local application of the powdered drug, which was used at operation in about 10 percent of all cases. Stool examinations made in the cases in which chemotherapy was used showed that, while there was not complete destruction of all micro-organisms, the colonies were always greatly reduced in number.

Irritation of the skin about the colostomy was an annoying consequence of sulfonamide therapy (fig. 45). It could usually be controlled by the use of



FIGURE 45.—Right-sided colostomy. Cecum and ascending colon exteriorized at time of injury. Note irritation of skin around colostomy, which was common in right-sided colostomies.

aluminum or kaolin paste. Secondary hemorrhage, another possible complication, was always potentially serious. Its prevention required careful prothrombin studies before operation and the administration of vitamin K in the immediate preoperative and postoperative period.

Penicillin was used extensively after it became available in the Zone of Interior in the spring of 1944. It was thought to be of great value in the prevention of infections caused by gram-positive organisms. Streptomycin did not become available until later and then only in hospitals designated for special studies. It was regarded as of great value in the prevention and treatment of gram-negative infections.

SUMMARY

The most important lesson to be derived from the large number of colostomies upon which this chapter is based is that the closure of the stoma created in the management of a battle-incurred injury of the colon is a safe and relatively simple procedure. In this series, almost every possible unfavorable circumstance was present from the moment of wounding. Initial treatment was carried out in a forward hospital, under field conditions. Even in fixed hospitals, treatment was conducted under the stress and strain of military conditions. The wounds were frequently of great gravity. Other wounds were frequently associated. In spite of these facts, the case fatality rate for closure of the colostomy was fractional, complications were relatively few, and practically every patient who survived was returned to normal activities and, from the standpoint of his intestinal injury, was in excellent condition on discharge.

In World War II, improvements in the technique of intestinal surgery, the intelligent use of replacement therapy and of chemotherapy and antibiotic therapy, and increasing experience on the part of responsible surgeons made it possible to close colostomies within relatively short periods after their creation. The wartime experience suggests that in future wars it may be possible to accomplish closure in all but the most complicated cases in overseas hospitals, without evacuating the patients to Zone of Interior hospitals. From a military standpoint, this would be a most important advance, for it would permit soldiers with wounds of the colon to return to full duty after relatively brief periods of disability and convalescence.

MEDICAL DEPARTMENT, UNITED STATES ARMY

The volumes comprising the history of the Medical Department of the United States Army in World War II are divided into two series: (1) The administrative and operational series, which constitutes a part of the general series of the history of the United States Army in World War II, prepared by The Surgeon General and published under the direction of the Chief of Military History; and (2) the professional, or clinical and technical, series, prepared by and published under the direction of The Surgeon General. This is one of the volumes published in the latter series.

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